Causal Relationship of Transverse Left Ventricular Band and Bicuspid Aortic Valve

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Abstract

Objectives: Bicuspid aortic valve is the most common congenital lesion found in adults. It is can be seen in combination with a transverse left ventricular (LV) band. We aimed to find an essential relationship between the presence of transverse ventricular band and bicuspid aortic valve. Methods: 13 patients with transverse left ventricular band were investigated during a 6 month period from January 2019 to July 2019. LV band thickness and gradients at the site of the LV band were evaluated as part of its effect on LV hemodynamics. Morphology of aortic valve and LV outflow tract gradients were assessed. We aimed to establish the presence of robust LV band as a surrogate marker for bicuspid aortic valve and evaluate the effect of LV band on LV hemodynamics. Results: Mean age of study population was 41yrs. Majority had bicuspid aortic valve(n=11). Average thickness of transverse band was 6.2mm and average mean aortic gradient was4mmHg. Sequestration of blood was noted at the level of transverse band in all the patients with 2 separate jets at LVOT. Anterolateral jet was deflected from transverse band and showed higher velocity in comparison to the other jet, causing turbulence at the bicuspid aortic valve. No co-relation was found between the thickness of transverse band and aortic valve gradient. Conclusion: Presence of a robust transverse LV band can serve as a surrogate marker for bicuspid aortic valve.
Keywords: Bicuspid aortic valve; aortic stenosis

Advances in knowledge
- Transverse LV band has been considered a vestigial part of the ventricle. However, the role played by these bands in presence of other disorders is intriguing.
- LV band is likely to play an important role in hemodynamics of bicuspid aortic valve.
- Bidirectional flow at the level of LV band may help to reduce the ventricular strain imposed by the increased afterload in the presence of bicuspid aortic valve.

Application to patient care
- In patients with aortic stenosis, determination of aortic valve morphology plays a crucial role in determining future management.
- In heavily calcified valves where valve morphology is not clear, detection of a thick robust LV band may serve as an indicator to the presence of a bicuspid aortic valve.

Introduction
Bicuspid aortic valve (BAV) is the most common congenital lesion found in adult population, with an overall prevalence of 1-2%\(^1\). Aortic stenosis and aortic regurgitation develop over time, with aortic stenosis being more common with increasing age\(^2\). The development of aortic stenosis imposes undue hemodynamic stress on the left ventricle. Bicuspid aortic valves are also associated with aortopathy which may be due to genetic or hemodynamic factors. These have far reaching consequences as they can lead to aortic aneurysm and aortic dissection\(^3\). Detection of BAV is done mainly with help of Transthoracic echocardiography (TTE). The diagnosis relies on the visualisation of two aortic cusps, with or without a raphe, and two commissures in the short-axis view. TTE has a sensitivity of 78% and specificity of 96% in the diagnosis of BAV\(^4\). However, the identification of bicuspid aortic valves can be difficult in the presence of severe calcification and fibrosis or a very prominent raphe which may masquerade as a third coaptation line. Detection of bicuspid etiology is necessary as these valves tend to undergo stenosis at an earlier age as compared to the tricuspid valves and more common to develop infective endocarditis\(^5,6\). Regular follow up is required for detection of any complications.
Transverse left ventricular (LV) band have been considered to be a benign anatomical variant, with similar incidence in patients with structural heart disease and normal hearts\(^7\). Studies have shown the presence of conduction tissue and myocardial cells in left ventricular bands, which could be a continuation of the His-bundle\(^8\). Transverse LV band has been associated with presence of early repolarisation changes on ECG\(^9\). However, they are not a specific substrate for arrhythmias like ventricular tachycardia\(^10\). Thick robust transverse LV bands are believed to be associated with increased wall stress of the left ventricle. Increased wall stress can be noted in conditions with raised afterload and left ventricular outflow obstruction (LVOTO) or in cases of bicuspid aortic valve\(^11\). Thus, presence of bicuspid aortic valves could be associated with thick robust left ventricular bands. In the current study, we aim to evaluate the relationship between bicuspid aortic valves and presence of transverse LV bands. We also aim to determine whether presence of robust LV band can give an indirect evidence of bicuspid morphology of stenosed aortic valve.

**Methods**
This is a prospective, observational single centre study conducted over a period of 6 months from January 2019 to July 2019. All patients who underwent 2-D transthoracic echocardiography (TTE) for the diagnosis of cardiac disease, were screened for the presence of transverse LV band. All patients, above 18 years of age, who were detected to have transverse LV band on TTE were included in our study. Patients with left ventricular dysfunction, poor echo window and ambiguous aortic valve morphology were excluded.

Baseline demographics and clinical characteristics, including risk factors of all the study participants were collected. Prior history of cardiac disease was evaluated. Coronary artery disease was defined as patients with history of myocardial infarction or angina and who were on regular anti-anginal and anti-platelet drugs. All the patients in the current study underwent TTE on Vivid T8 (GE Healthcare systems, Chicago, USA) machine using a linear echocardiography probe of 3.5 MHz frequency. LV bands visible in at least 2 views were considered as definite. Left ventricular internal dimensions and ejection fraction was recorded. Presence of wall motion abnormality and valvular disease were noted. The characteristics of the LV bands were noted in terms of position, extent, point of insertion and average dimension. The effect of LV band on LV hemodynamics was also evaluated. The dimensions of LV band were co-related with severity of outflow gradient.
Baseline data was collected using a structured questionnaire. Data is presented as summary statistics. Categorical variables have been presented as proportions whereas continuous variables have been presented as mean and standard deviation. Co-relation analysis using Spearman’s correlation was done to evaluate the relationship between dimensions of LV band and aortic valve gradients. All statistical analysis was performed using SPSS v25 (Armonk, NY, USA). Informed written consent was obtained from the patients. The current study was approved for exemption from institutional permission by the review board.

Results
A total of 13 patients were included in the study. The baseline demographics have been noted in Table 1. The mean age of the study population was 41 yrs. Males comprised 54% (n=7) of study population. Majority (85%) of the patients had a bicuspid aortic valve (Figure 1). Transverse left ventricular band was noted in all the patients (Figure 2). The average thickness of the LV band imaged was 6.2mm. The most robust LV band had dimensions of 8mm (n=5) whereas the most slender band had dimensions of 3mm (n=1). The average aortic valve area for patients with LV band was 1.6 ± 0.67 cm² whereas average indexed aortic valve area was 1.05 ± 0.47 cm²/m². Average peak gradient across the aortic valve was noted to be 24mm Hg and average peak velocity was 2.3 m/s. Mean aortic gradient in the study population was 14.1 ± 11.3 mmHg. Sequestration of blood was noted at the level of transverse band in all the patients (Figure 3). Majority of cases demonstrated 2 separate jets at the LVOT. The septal side of LVOT demonstrated a straight jet from the LV apex while the anterolateral jet was deflected from the transverse LV band towards the LVOT. Pulse wave Doppler analysis revealed that the anterolateral jet had higher velocity than the septal jet and caused turbulence at the bicuspid valve (Figure 4). Co-relation analysis showed that there was no significant co-relation between the aortic valve gradient and thickness of LV band (r=0.423, p value=0.15). Aortic valve area also did not show any significant correlation with LV band thickness(r=-0.48, p value=0.09).

Discussion
The current study aims to evaluate the relationship between transverse LV band and bicuspid aortic valve. Majority of the patients in the present study were young individuals without major comorbidities. All the patients had normal ventricular function on echocardiography with majority having a bicuspid aortic valve. Distinct transverse LV band was noted in all
these patients. A previous study had associated the presence of LV band with structural and functional changes involving LV systolic and diastolic dysfunction\textsuperscript{12}. However, none of the patients in our study had any evidence of systolic or diastolic dysfunction. The same study also found that transverse LV bands are associated with mitral regurgitation\textsuperscript{12}.

Based on the orientation of the LV band, different types of LV band have been described in literature. The most common location of LV band is between the posteromedial papillary muscle and ventricular septum\textsuperscript{13}. It has been proposed that the transverse LV band, which straddle the septum and the lateral wall of the ventricle, prevent ventricular dilatation in the event of ventricular remodelling\textsuperscript{14}. Presence of LV band between posteromedial papillary muscle and septum can prevent ventricular dilatation after an infero-posterior wall myocardial infarction. Similarly, LV band located between the free wall and the septum can inhibit ventricular dilatation after an anterior wall myocardial infarction. Reduction in ventricular dilatation during remodelling can also reduce tethering of mitral leaflets, which can effectively reduce functional mitral regurgitation\textsuperscript{14}. Thus the presence of transverse LV band may be associated with preservation of ventricular architecture. This can account for the non-dilated ventricles in the present study, despite the presence of increased hemodynamic stress of bicuspid aortic valve and aortic stenosis.

Presence of bicuspid aortic valve, with or without valvular dysfunction, can impose a significant hemodynamic burden on the left ventricle. Studies using cardiac MRI have demonstrated markedly abnormal helical flow in ascending aorta in BAV patients\textsuperscript{15}. This abnormal flow was also seen in BAV patients without any degree of stenosis or aortic aneurysm. Abnormal leaflet motion during cardiac cycle (wrinkling of valve tissue, excessive doming of valve leaflets) was noted, which results in increased turbulence across the valve, even when the valve is not stenotic. The cause of abnormal motion is probably unequal leaflet length. Turbulent flow across aortic orifice can produce shear stress and lead to medial degeneration via activation of matrix metalloproteinase pathways. Barker et al used computational flow dynamics in MRI to investigate wall shear stress in patients with BAV\textsuperscript{16}. All patients with BAV had abnormal flow in the ascending aorta and transverse arch while flow was completely normal in patients with tricuspid aortic valve. BAV patients are likely to have jet flow impingement along the greater curvature of the ascending aorta, leading to wall shear stress\textsuperscript{17}. LV parameters have also been studied in the presence of bicuspid aortic valve. In a cohort of 58 children with bicuspid aortic valve, cardiac MRI showed that elevated aortic
peak velocity and wall shear stress (WSS) had a negative co-relation with LV global longitudinal strain\textsuperscript{18}. Cardiac MRI analysis in a cohort of BAV subjects showed that patients with valvular dysfunction had significantly elevated LV mass and peak WSS in the ascending aorta\textsuperscript{19}. A positive co-relation was noted between extracellular volume (ECV) fraction and aortic WSS, indicating significant ventricular remodelling in the face of elevated shear stress. All this evidence points to presence of elevated hemodynamic stress on left ventricle in the presence of bicuspid aortic valve, which predisposes to ventricular remodelling.

LV needs a compensatory mechanism to counteract this hemodynamic burden. This probably manifests in the form of hypertrophied LV band. The hypertrophied LV band contain myocardial tissue and conductive tissue. They have property of contraction and relaxation. Thus, they can prevent overstretching of LV\textsuperscript{20}. Transverse LV band help to sequester blood proximally during diastole and diverts it towards the LVOT in an effort to reduce the hemodynamic stress during systole\textsuperscript{21}. The hypertrophy of LV band is related to the added hemodynamic stress posed by the bicuspid aortic valve, where it attempts to prevent LV dilatation and remodelling. This is why patients with low aortic gradients and bicuspid aortic valve also showed hypertrophied transverse band. The thickness of transverse band was usually similar to moderator band of RV in the current study. There was no definite co-relation found between the thickness of LV band and aortic valve gradient or the aortic valve area in our study. However, we could demonstrate presence of robust LV band in all patients with bicuspid aortic valve in our series. There is paucity of data on the presence of transverse LV band in patients with bicuspid aortic valve and aortic stenosis. Further studies are required to delineate the LV hemodynamics in patients with bicuspid aortic valve and LV band. MRI studies can help in determining the changes in ventricular remodelling observed in patients with bicuspid aortic valve and transverse LV band. Echocardiography has been a robust modality for detection of transverse LV bands. Hypertrophied LV bands are usually a response to elevated hemodynamic stress. Thus, in conditions where aortic valve morphology is not clear due to heavy calcification, presence of a robust LV band may give an indication towards presence of bicuspid aortic valve, in the absence of other confounding factors like ventricular dilatation and mitral regurgitation.

The current study has many limitations. Firstly, sample size was small due to financial constraints. Secondly, complete dimensions of LV band could not be measured by echo and only thickness was taken as marker of the robustness of the structure. Thirdly, cardiac MRI
could not be performed to evaluate LV remodelling in patients with bicuspid aortic valve and LV band, due to financial and availability constraints. Larger studies are warranted in patients with bicuspid aortic valve and LV band to understand the interplay of hemodynamics.

**Conclusion**

Presence of a robust transverse LV band may serve as a surrogate marker for bicuspid aortic valve. Larger studies with cardiac MRI are required to prove the definite association between robust LV band and dysfunctional bicuspid aortic valve.

**Conflict of Interest**

The authors declare no conflicts of interest.

**Funding**

No funding was received for this study.

**References**


Figure 1: A. Parasternal short axis view (PSAX) showing a bicuspid aortic valve in the open state during ventricular systole. B. PSAX showing a bicuspid aortic valve with a raphe.

Figure 2: A,B,C. Parasternal and apical long axis view show a robust left ventricular band (arrows) extending from the interventricular septum to the posterior wall of the left ventricle.
Figure 3: Pulse wave doppler at the level of transverse band shows bidirectional flow due to deflection of blood by the band.

Figure 4: Pulse wave doppler analysis of septal jet(A) and anterolateral jet(B) in left ventricular outflow tract showed higher velocity of anterolateral jet.
Table 1: Baseline demographics of the study population. AR- aortic regurgitation, LVEDD – Left ventricular end-diastolic dimension, LVESD – Left ventricular end-systolic dimension.

<table>
<thead>
<tr>
<th>Baseline Demographics</th>
<th>N=13</th>
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<tbody>
<tr>
<td>Age, mean(SD)</td>
<td>41.1 (12.9)</td>
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<tr>
<td>Males, n(%)</td>
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<tr>
<td>Body surface area, mean (SD)</td>
<td>1.62 (0.34)</td>
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<td>Diabetes mellitus, n(%)</td>
<td>3 (23)</td>
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<tr>
<td>Hypertension, n(%)</td>
<td>7 (53.8)</td>
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<tr>
<td>Dyslipidemia, n(%)</td>
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<tr>
<td>Family history of cardiac disease, n(%)</td>
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<tr>
<td>Coronary artery disease, n(%)</td>
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<tr>
<td>Left ventricular internal dimension, mm</td>
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<tr>
<td>LVEDD, mean (SD)</td>
<td>43.6 (6.3)</td>
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<td>LVESD, mean (SD)</td>
<td>26.8 (5.4)</td>
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<tr>
<td>Left ventricular ejection fraction, mean(SD)</td>
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<td>Peak aortic gradient in mmHg, mean (SD)</td>
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<tr>
<td>Mean aortic gradient in mmHg, mean(SD)</td>
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<tr>
<td>AR grade 2+, n(%)</td>
<td>2 (15.4)</td>
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<tr>
<td>Aortic valve area in cm², mean (SD)</td>
<td>1.62 (0.67)</td>
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<td>Indexed aortic valve area in cm²/m², mean(SD)</td>
<td>1.05 (0.47)</td>
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<td>Transverse LV band thickness in mm, mean (SD)</td>
<td>6.2 (1.8)</td>
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