Sultan Qaboos University Med J, August 2021, Vol. 21, Iss. 3, pp. 403–407, Epub. 29 Aug 21
Submitted 5 Jul 20
Revision Req. 3 Sep 20; Revision Recd. 17 Sep 20
Accepted 4 Oct 20
https://doi.org/10.18295/squmj.4.2021.020

CLINICAL & BASIC RESEARCH

Causal Relationship of the Transverse Left Ventricular Band and Bicuspid Aortic Valve

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abstract: ***Objectives:*** Bicuspid aortic valve (BAV) is the most common congenital lesion found in adults. It can be seen in combination with a transverse left ventricular (LV) band. This study aimed to find an essential relationship between the presence of transverse ventricular band and BAV. ***Methods:*** A total of 13 patients from a tertiary care centre in India with transverse LV band were investigated during a six-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 haemodynamics. The morphology of the aortic valve and LV outflow tract gradients was assessed. ***Results:*** The mean age of the participants was 41 years. A majority had a BAV (n = 11). Average thickness of the LV band was 6.2 mm and the average mean aortic gradient was 4 mmHg. Sequestration of blood was noted at the level of the transverse band in all the patients with two separate jets at the left ventricular outflow tract. The anterolateral jet was deflected from the transverse band and showed higher velocity compared to the other jet, causing turbulence at the BAV. No correlation was found between the thickness of the transverse band and aortic valve gradient. ***Conclusion:*** Presence of a robust transverse LV band can serve as a surrogate marker for BAV.

Keywords: Bicuspid Aortic Valve; Aortic Stenosis; Ventricular Outflow Obstruction; Hemodynamics.

Advances in Knowledge

- *Transverse left ventricular (LV) band has been considered a vestigial part of the ventricle. However, the role played by this band in presence of other disorders is insufficiently known.*
- *LV band is likely to play an important role in the haemodynamics of the bicuspid aortic valve (BAV).*
- *Bidirectional flow at the level of the LV band may help reduce the ventricular strain imposed by the increased afterload in the presence of the BAV.*

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 unclear, detection of a thick robust left ventricular (LV) band may serve as an indicator to the presence of a bicuspid aortic valve (BAV).*

The bicuspid aortic valve (BAV) is the most common congenital lesion found in the adult population, with an overall incidence of 0.4–2.2%.[1] Aortic stenosis and aortic regurgitation develop over time, with aortic stenosis being more common among those whose age has advanced. The development of aortic stenosis imposes undue haemodynamic stress on the left ventricle.[2] BAVs are also associated with aortopathy which may be due to genetic or haemodynamic factors. These have far-reaching consequences as they can lead to aortic aneurysm and aortic dissection.[3] Detection of BAV is done mainly with the 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 87.7% and specificity of 88.3% in the diagnosis of BAV.[4] However, the identification of BAVs can be difficult in the presence of severe calcification and fibrosis or a very prominent raphe, which may be masquerading as a third coaptation line. Detection of bicuspid aetiology is necessary as these valves tend to undergo stenosis at an earlier age as compared to the tricuspid valves and can more commonly develop infective endocarditis.[6,7] Regular follow-up is required for the detection of any complications.

The transverse left ventricular (LV) band has been considered to be a benign anatomical variant, with similar incidence in patients with structural heart disease and a normal heart.[8] Several studies have shown the presence of the conduction tissue and myocardial cells in LV bands, which are in continuity with left bundle branch of the conduction system.[8,9] The transverse LV band has been associated with the presence of early repolarisation changes on an electrocardiogram.[10] However, they are not a specific substrate for arrhythmias such as ventricular tachycardia.[11] Thick robust transverse LV bands are believed to be associated with increased wall stress of the left ventricle. Increased wall stress can be noted

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in conditions with raised afterload and LV outflow obstruction (LVOTO) or in the case of BAV.[12] Thus, the presence of BAVs could be associated with thick robust LV bands. This study aimed to evaluate the relationship between BAVs and the presence of transverse LV bands. Another aim of this study was to determine whether the presence of a 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 at a tertiary care hospital in India, over a period of six months from January 2019 to July 2019. All patients who underwent two-dimensional TTE for the diagnosis of a cardiac disease were screened for the presence of transverse LV band. The patients, above 18 years of age who were detected to have transverse LV band via TTE were included in this study, whereas patients with LV 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 in terms of a patient having a history of myocardial infarction or angina on regular anti-anginal and anti-platelet drugs. All the patients in the current study underwent TTE on the Vivid T8 machine (GE Healthcare Systems, Chicago, USA), using a linear echocardiography probe of 3.5 MHz frequency. Those LV bands that were visible in at least two views were considered to be definite. The internal LV dimensions and ejection fraction were recorded. The presence of wall motion abnormality and valvular disease was also noted alongside the characteristics of the LV bands in terms of position, extent, point of insertion and average dimension. Thereafter, the effect of the LV bands on LV haemodynamics was evaluated and the dimensions of the LV band were correlated with the severity of the outflow gradient.

Baseline data were collected using a structured questionnaire and have been presented as summary statistics. Categorical variables have been presented as proportions, whereas continuous variables have been presented as means and standard deviations. The correlation analysis was conducted using Spearman's correlation coefficient to evaluate the relationship between the dimensions of the LV bands and aortic valve gradients. All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) Version 25.0 (IBM Corp., Armonk, New York, USA). Informed and written consent was obtained from the patients. This study was approved for exemption from institutional permission by the Institutional Review Board.

Table 1: Baseline demographic characteristics of patients with a bicuspid aortic valve (N =13)

Baseline Characteristics	Mean ± SD
Age in years	41.1 ± 12.9
Body surface area in metres	1.62 ±0.34
Left ventricular internal dimension (in mm)	
LVEDD	43.6 ± 6.3
LVESD	26.8 ± 5.4
Left ventricular ejection fraction	69.6 ± 4.5
Peak aortic gradient in mmHg	24.5 ± 16.3
Mean aortic gradient in mmHg	14.1 ± 11.3
Aortic valve area in cm^2	1.62 ± 0.67
Indexed aortic valve area in cm^2/m^2	1.05 ± 0.47
Transverse LV band thickness in mm	6.2 ± 1.8
Baseline Characteristics	**n (%)**
Males	7 (53.8)
Females	6 (46.2)
Diabetes mellitus	3 (23.1)
Hypertension	7 (53.8)
Dyslipidaemia	4 (30.7)
Family history of cardiac disease	0 (0)
Coronary artery disease	2 (15.4)
AR grade 2+	2 (15.4)

SD=standard deviation; LVEDD = left ventricular end-diastolic dimension; LVESD = left ventricular end-systolic dimension; LV = left ventricle; AR = aortic regurgitation.

Results

A total of 13 patients were included in this study. The mean age of the study population was 41.1 years with males comprising 53.8% (n = 7) of the participants

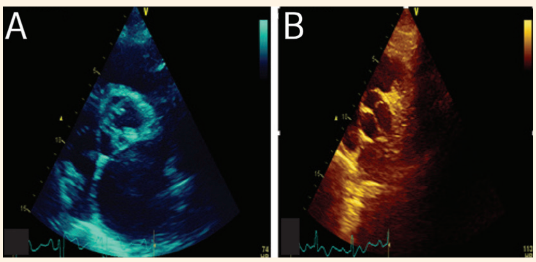

Figure 1: Parasternal short axis view showing a bicuspid aortic valve **(A)** in the open state during ventricular systole **(B)** with a raphe in a patient obtained via transthoracic echocardiography.

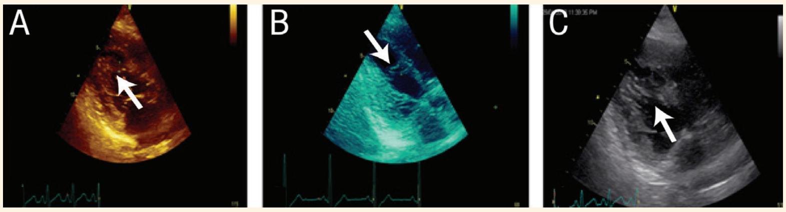

Figure 2: Parasternal and apical long axis views showing a robust left ventricular band (arrows) extending from the interventricular septum to the posterior wall of the left ventricle obtained via transthoracic echocardiography.

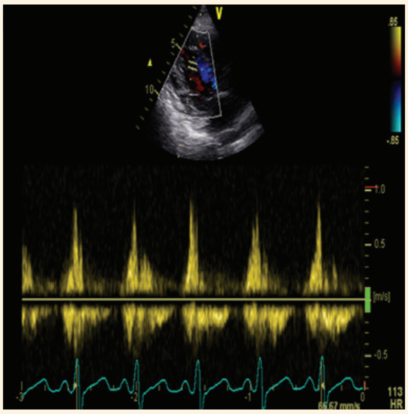

Figure 3: Pulse wave Doppler at the level of transverse band showing bidirectional flow due to deflection of blood by the band in a patient with a bicuspid aortic valve.

[Table 1]. Majority (85%) of the patients had a BAV [Figure 1] and transverse LV band was noted in all the patients [Figure 2].

The average thickness of the LV band imaged was 6.2 mm. The most robust LV band had a dimension of 8 mm (n = 5), whereas the slenderest band had a dimension of 3 mm (n = 1). The average aortic valve area for patients with LV band was 1.62 ± 0.67 cm^2, whereas the average indexed aortic valve area was 1.05 ± 0.47 cm^2/m^2. The average peak gradient across the aortic valve was noted to be 24.5 mmHg and the 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 the transverse band in all the patients [Figure 3].

Most cases (80%) demonstrated two separate jets at the left ventricular outflow tract (LVOT). The septal side of the 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 a higher velocity than the septal jet and caused turbulence at the bicuspid valve [Figure 4].

The correlation analysis showed that there was no significant correlation between the aortic valve gradient and thickness of the LV band (r = 0.423; *P* = 0.15). Furthermore, the aortic valve area did not show any significant correlation with LV band thickness (r = −0.48; *P* = 0.09).

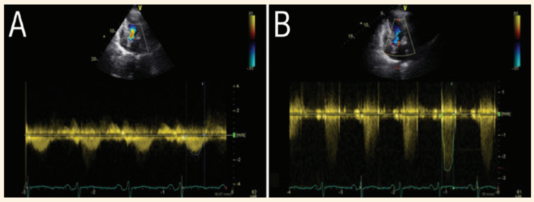

Figure 4: Pulse wave doppler analysis of **(A)** septal jet and **(B)** anterolateral jet in the left ventricular outflow tract showing higher velocity of anterolateral jet in a patient with a bicuspid aortic valve.

Discussion

The current study aimed to evaluate the relationship between transverse LV band and BAV. A majority of the patients participating in this study were young individuals without major comorbidities. All the patients had normal ventricular function on echocardiography with a majority of them having a BAV. Distinct transverse LV bands were noted in all of these patients. A previous study had associated the presence of LV band with structural and functional changes involving LV systolic and diastolic dysfunction.[13] However, none of the patients in the current study had any evidence of systolic or diastolic dysfunction. The same study had also found that transverse LV bands are associated with mitral regurgitation.[13]

Based on the orientation of the LV band, different types of LV bands have been described in the relevant literature. The most common location of the LV band is between the posteromedial papillary muscle and ventricular septum.[14] It has been proposed that the transverse LV band which straddles the septum and the lateral wall of the ventricle prevents ventricular dilatation in the event of ventricular remodelling.[15] The presence of LV band between the posteromedial papillary muscle and septum can prevent ventricular dilatation after an infero-posterior wall myocardial infarction. Similarly, the LV band located between the free wall and the septum can inhibit ventricular dilatation after an anterior wall myocardial infarction. A reduction in the ventricular dilatation during remodelling can also reduce tethering of mitral leaflets, which can effectively reduce functional mitral regurgitation.[15] Thus, the presence of a transverse LV band may be associated with the preservation of the ventricular architecture. This can account for the non-dilated ventricles observed during the present study despite the presence of increased haemodynamic stress of BAV and aortic stenosis.

The presence of BAV with or without the valvular dysfunction can impose a significant haemodynamic burden on the left ventricle. Studies using cardiac magnetic resonance imaging (MRI) have demonstrated markedly abnormal helical flow in ascending aorta in BAV patients. This abnormal flow was also seen in BAV patients without any degree of stenosis.[16] An abnormal leaflet motion during cardiac cycle (wrinkling of valve tissue and excessive doming of valve leaflets) was noted in the current study, which resulted in an increased turbulence across the valve even when the valve was not stenotic. The cause of such abnormal motion is probably the unequal leaflet length. A turbulent helical flow across the aortic orifice can produce shear stress and lead to medial degeneration via the activation of matrix metalloproteinase pathways.[17] Barker *et al.* used computational flow dynamics in MRI to investigate wall shear stress (WSS) in patients with BAV.[18] All patients with BAV had abnormal flow in the ascending aorta and transverse arch, while the 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 WSS.[19] LV parameters have also been studied in the presence of BAV. In a cohort of 58 children with BAV, cardiac MRI showed that elevated aortic peak velocity and WSS had a negative correlation with LV global longitudinal strain.[20] 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.[21] A positive correlation was noted between extracellular volume fraction and aortic WSS, indicating significant ventricular remodelling in the face of elevated shear stress. All this evidence points to the presence of elevated haemodynamic stress on the left ventricle in the presence of BAV, which predisposes it to ventricular remodelling.

The left ventricle needs a compensatory mechanism to counteract this haemodynamic burden. This can manifest in the form of the hypertrophied LV band. The hypertrophied LV band contains myocardial tissue and conductive tissue having properties of contraction and relaxation. Thus, they can prevent the overstretching of the left ventricle.[22] The transverse LV band helps to sequester blood proximally during diastole and diverts it towards the LVOT in an effort to reduce the haemodynamic stress during systole.[21] The hypertrophy of the LV band is likely related to the added haemodynamic stress posed by the BAV where it attempts to prevent LV dilatation and remodelling. The authors hypothesise that this may be the probable reason for hypertrophied LV bands in BAV patients with low aortic gradients. The thickness of the transverse band was usually similar to the moderator band of the right ventricle as observed in this study. Furthermore, no definite correlation was found between the thickness of the LV band and the aortic valve gradient or the aortic valve area in the current study. However, the presence of a robust LV band in all patients with BAV could not be demonstrated in this series. There is paucity of data on the presence of transverse LV band in patients with BAV and aortic stenosis. Further studies are required to delineate the LV haemodynamics in patients with BAV and LV band. MRI studies can help in determining the changes in ventricular remodelling observed in patients with BAV and transverse LV band. Echocardiography has been a robust modality for the detection of transverse LV bands.[15] Thus, in conditions where the aortic valve morphology is not clear due to heavy calcification, the presence of a robust LV band may offer an indication of the presence of BAV in the absence of other confounding factors such as ventricular dilatation and mitral regurgitation.

This study had some limitations. First, the sample size was small due to financial constraints. Second, complete dimensions of the LV band could not be measured by echocardiography and only thickness was taken as a marker of the robustness of the structure. Finally, cardiac MRI could not be performed to evaluate LV remodelling in patients with BAV and LV band due to financial constraints and lack of availability of MRI facilities at our centre. Larger studies are warranted in patients with BAV and LV band to understand the interplay of haemodynamics.

Conclusion

The presence of a robust transverse LV band may serve as a surrogate marker for BAV. Larger studies using cardiac MRI are required to prove a definite association between robust LV band and dysfunctional BAV.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

No funding was received for this study.

Authors' contribution

MKD and AM were involved with the conceptualisation and design of the study as well as data collection and analysis. MKD, AM and VO equally contributed to the preparation of the manuscript. VO was responsible for image preparation and graphics. All the authors reviewed and approved the final version of the manuscript.

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