Original Article

# Noninvasive left ventricular pressure-strain myocardial work in patients with well-functioning bicuspid aortic valves and aortic dilation: a preliminary study

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**Background:** Noninvasive left ventricular pressure-strain myocardial work (MW) is a novel method for evaluating left ventricular function that integrates myocardial deformation and afterload and has certain advantages over global longitudinal strain (GLS). The study aimed to analyze MW in patients with well-functioning bicuspid aortic valve (BAV) and explore the influences of aortic dilation and arterial stiffness on left ventricular function.

**Methods:** A total of 104 patients with well-functioning BAVs and 50 controls were enrolled in our study. Global work index (GWI), global constructive work (GCW), global wasted work (GWW), global work efficiency (GWE), GLS, and aortic stiffness index were measured. Based on the ascending aortic diameter, patients with BAV were divided into 3 subgroups (nondilated, mildly dilated, and moderately dilated).

**Results:** GWI, GCW, GWW, and aortic stiffness index were significantly increased (P<0.001, P=0.023, P<0.001, and P<0.001, respectively), while GWE and GLS were significantly decreased among patients with BAV compared with controls (all P values <0.001). Patients with BAV and mildly and moderately dilated aortas had an increased GWW and aortic stiffness index but a decreased GWE compared with patients with BAV and nondilated aortas (all P values <0.05); meanwhile, GCW and GLS did not differ among the BAV subgroups (all P values >0.05). GWI was elevated in patients with BAV and moderately dilated aortas compared with patients with BAV and nondilated aortas (P<0.05). On multivariable analysis, the aortic stiffness index was an independent influencer of GWI, GCW, GWW, and GWE (P=0.025, P=0.049, P<0.001, and P=0.001, respectively). The aortic diameter was highly correlated with the aortic stiffness index (r=0.863; P<0.001).

**Conclusions:** MW could assess early myocardial impairment in patients with well-functioning BAV. MW may help to differentiate the detrimental effect of aortic dilation on left ventricular function, whereas GLS may not.

**Keywords:** Myocardial work (MW); bicuspid aortic valve (BAV); aortic stiffness index; aortic dilation

Submitted Mar 08, 2023. Accepted for publication Jul 28, 2023. Published online Sep 01, 2023.
doi: 10.21037/qims-23-294
**View this article at:** https://dx.doi.org/10.21037/qims-23-294

## Introduction

Bicuspid aortic valve (BAV) is a complex and heterogeneous disease that can be understood fundamentally as a form of valvulo-aortopathy (1). Patients with BAV have altered molecular and/or metabolic characteristics in the aortic wall, with a loose attachment of vascular smooth muscle cells and a higher collagen content and matrix metalloproteinases (MMP)-2 expression even without significant valvular dysfunction (2,3). Therefore, approximately 70% of patients with BAV exhibit ascending aortic dilation and arterial stiffness alteration (4). Dilated ascending aorta and increased arterial stiffness may impair left ventricular (LV) systolic function through ventricular–arterial coupling (5). The related research has highlighted that accurate and early evaluation of myocardial function is important in patients with well-functioning BAV (6). Ejection fraction (EF) and global longitudinal strain (GLS) are the mainstay methods for quantifying LV function; however, they may be limited by the influence of loading conditions (7). Therefore, they may function less reliably as markers of myocardial function when the LV is under abnormal loading due to bicuspid aortopathy, as an increased afterload has already been proven to decrease strain (8). Noninvasive myocardial work (MW) derived from LV pressure-strain loops, which considers both deformation and afterload, is an advanced mode of assessment for LV myocardial mechanics. Moreover, noninvasive MW has been demonstrated to have a robust correlation with invasive MW, myocardial oxygen consumption, and local myocardial glucose metabolism (9,10), offering comprehensive information for myocardial performance. Nonetheless, research into noninvasive MW in patients with well-functioning BAV has thus far been scarce. Therefore, in this study, we attempted (I) to investigate the potential value of noninvasive LV pressure-strain MW in patients with well-functioning BAV and (II) to examine the influence of aortic dilation and arterial stiffness on LV function.

## Methods

### *Patient dentification*

A total of 104 patients with BAV were included from Wuhan Union Hospital. BAV was diagnosed based on the left parasternal short-axis views, with the presence of 2 commissures delimiting only 2 aortic valve cusps with a "fish mouth" appearance of the orifice during systole being visualized from transthoracic echocardiography (11). The definition of well-functioning BAV is less-than-mild aortic stenosis (mean gradient <20 mmHg) or regurgitation. The exclusion criteria were as follows: (I) patients with more-than-mild aortic stenosis (mean gradient ≥20 mmHg) and/or aortic regurgitation and those with more-than-mild mitral/tricuspid stenosis and/or mild mitral/tricuspid regurgitation; (II) patients with a history of cardiac-related interventions or revascularization procedures; (III) patients with genetic, hematologic, oncologic, or rheumatic diseases; (IV) patients with cardiac arrhythmias; and (V) patients with poor acoustic windows. In addition, 50 age and gender-matched healthy individuals with tricuspid aortic valves were selected as controls. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Human Subjects Review Committee at Wuhan Union Hospital (No. UHCT22412). Individual consent for this retrospective analysis was waived.

### *Echocardiography*

All patients underwent comprehensive transthoracic echocardiography with a commercially available ultrasound machine (GE HealthCare, Chicago, IL, USA). Echocardiographic data from 5 consecutive cardiac cycles were stored digitally in cine-loop format with a frame rate >50 frames/s. All conventional echocardiographic parameters were measured according to guidelines established by the American Society of Echocardiography and the European Society of Cardiovascular Imaging (12). EF was estimated using Simpson's biplane method, and LV mass was calculated using the relevant formula and indexed for body surface area. LV diastolic function was assessed using Doppler mitral inflow. The peak early diastolic (E), late diastolic (A) filling velocities, and the E/A ratio were calculated. Peak early (e') velocities were measured at the septal and lateral aspects of the mitral annulus. E/e' was calculated from the E velocities and the mean e' velocities obtained from the septal and lateral positions of the mitral annulus.

 

Aortic diameter in systole (AoS) and diastole (AoD) were measured in a parasternal long-axis view leading edge to leading edge, 2–3 cm above the aortic annulus. The aortic stiffness index was calculated according to the ascending aortic diameter and the corresponding systolic blood pressure (SBP) and diastolic blood pressure (DBP) as follows: aortic stiffness index = ln (SBP/DBP)/[(AoS – AoD)] × AoD (13). Based on the ascending aortic diameter, patients with BAV were divided into nondilated (ascending aortic diameter ≤3.5 cm), mildly dilated (3.5 cm < ascending aortic diameter <4.0 cm), and moderately dilated (ascending aortic diameter ≥4.0 cm) (14,15).

### *Left ventricular strain and MW analysis*

Workstation software (EchoPAC 204, GE HealthCare) was used to analyze cine-loop dynamic echocardiographic images offline. MW was quantified using the workstation's semiautomatic software package, which determined aortic valve opening and closing times in 3-chamber views. In addition to the software's automatic tracking detection, the tracking's completeness was visually confirmed by 2 experienced sonographers. If necessary, sonographers could adjust the region of interest by manually correcting the endocardial border or width. GLS was calculated from the average of the peak longitudinal strains in a 17-segment model.

The peak systolic LV pressure was assumed to be equal to the peak arterial systolic pressure based on the brachial blood pressure. After completion of the GLS analysis, the brachial blood pressure was input into the software package, which could automatically construct a noninvasive LV pressure curve based on the synchronizing longitudinal strain, blood pressure, and the time of valvular events. The 4 following parameters of MW were derived.

(I) Global work index (GWI)—the total work performed by the LV from the mitral valve closure to mitral valve opening, which was the sum of the MW;
(II) Global constructive work (GCW)—the work done by LV systolic myocardial shortening and isovolumic diastolic myocardial lengthening, considered to be the "positive" work contributing to LV ejection;
(III) Global wasted work (GWW)—the work done by LV lengthening during systole and shortening during isovolumic diastole, considered to be the "negative" work of LV ejection;
(IV) Global work efficiency (GWE)—the percentage of total LV work that was useful to contractions during systole and relaxation during diastole, calculated as GCW/(GCW + GWW) × 100% (16).

### *Reproducibility of GLS and MW parameters*

In the BAV cohort, 20 patients were randomly selected to verify the reproducibility of GLS and the MW parameters. Among them, intraobserver reproducibility was achieved by 2 experienced sonographers evaluating at least 2 weeks apart. These 2 experienced sonographers achieved interobserver reproducibility using the same method in a double-blind situation.

### *Statistical analysis*

Data analysis was performed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA) and GraphPad Prism version 9.0.0 (GraphPad Software, San Diego, CA, USA). The Shapiro-Wilk test verified the continuous values for the normality of the data distribution. Normally distributed continuous variables are expressed as the mean ± standard deviation (SD), and nonnormally distributed continuous variables are expressed as the median with quartiles. Categorical variables are expressed as absolute values and percentages. Comparisons of continuous variables between groups were performed using 1-way analysis of variance (ANOVA) or the Mann-Whitney test, with the Bonferroni correction test being used for multiple comparisons. Categorical variables were compared between groups using chi-squared analysis or Fisher exact test. The relationships between aortic stiffness index, MW parameters, GLS were calculated using linear regression analysis. Spearman rank correlation was used to calculate the association between the aortic diameter and aortic stiffness index. Intraobserver and interobserver variability were calculated using interclass correlation coefficient (ICC), with the excellent agreement being an ICC greater than 0.75. All tests were 2-tailed, and a P value <0.05 was considered statistically significant.

## Results

### *Patients demographics and echocardiographic parameters*

The study population consisted of 154 individuals: 104 patients diagnosed with BAV (mean age 45.89±12.79 years; 75% men) and 50 healthy controls (mean age 46.16±

**Table 1** Conventional baseline and echocardiographic parameters

| Variables | Control (N=50) | All patients with BAV (N=104) | P value |
|---|---|---|---|
| Age (years) | 46.16±9.97 | 45.89±12.79 | 0.897 |
| Men, n (%) | 32 (64.00) | 78 (75.00) | 0.157 |
| Heart rate (bpm) | 74.08±9.13 | 75.40±10.22 | 0.438 |
| Body surface area ($m^2$) | 1.66±0.17 | 1.70±0.17 | 0.213 |
| Systolic blood pressure (mmHg) | 120.66±8.00 | 124.22±10.61 | 0.037 |
| Diastolic blood pressure (mmHg) | 79.10±9.06 | 81.20±8.54 | 0.163 |
| Hypertension, n (%) | 0 (0.00) | 30 (28.85) | <0.001 |
| Interventricular septum index ($cm/m^2$) | 0.45±0.07 | 0.47±0.11 | 0.105 |
| End-diastolic volume index ($mL/m^2$) | 55.12±16.13 | 60.41±16.11 | 0.059 |
| EF (%) | 65.47±1.54 | 65.07±1.72 | 0.165 |
| LV mass index ($g/m^2$) | 62.42±7.22 | 78.07±14.01 | 0.000 |
| E/A | 1.22±0.21 | 1.18±0.20 | 0.261 |
| E/e' average | 7.03±0.94 | 7.17±1.22 | 0.450 |
| Ascending aortic diameter (cm) | 3.08±0.26 | 3.76±0.68 | <0.001 |
| Ascending aortic diameter index ($cm/m^2$) | 1.87±0.21 | 2.23±0.44 | <0.001 |
| Aortic stiffness index (β) | 3.97±0.36 | 5.30±1.50 | <0.001 |
| GLS (%) | 22.07±0.53 | 19.42±0.92 | <0.001 |
| GWI (mmHg%) | 1,749.34±95.74 | 1,838.47±113.14 | <0.001 |
| GCW (mmHg%) | 2,096.46±121.29 | 2,159.20±173.85 | 0.023 |
| GWW (mmHg%) | 57.64±15.74 | 98.08±29.05 | <0.001 |
| GWE (%) | 96.92±0.75 | 95.04±1.19 | <0.001 |

Normally distributed continuous variables are expressed as the mean ± SD. Categorical variables are expressed as absolute values and percentages. BAV, bicuspid aortic valve; LV, left ventricular; EF, ejection fraction; E, peak early diastolic mitral flow velocity; A, late diastolic mitral inflow velocity; e', peak early diastolic mitral annular velocity; GLS, global longitudinal strain; GWI, global work index; GCW, global constructive work; GWW, global wasted work; GWE, global work efficiency.

9.97 years; 64% men). Demographics and echocardiographic parameters of the total BAV population and controls are presented in *Table 1*. Compared with controls, patients with BAV showed increased GWI, GCW, and GWW but decreased GWE and GLS (all P values <0.05). SBP, ascending aortic diameter, aortic stiffness index, and LV mass index in patients with BAV were higher than those in controls (all P values <0.05).

### *Demographics and echocardiographic parameters of patients with BAV stratified by ascending aortic diameter*

Data on demographics and echocardiographic parameters in the BAV subgroups stratified by ascending aortic diameter are described in *Table 2*. GWW was increased, and GWE was decreased in BAV patients with mildly or moderately dilated aortas as compared with those with nondilated aortas (all P values <0.05), whereas GCW did not differ among the BAV subgroups (all P values >0.05). GWI was increased in patients with BAV with moderately dilated aortas compared with those with nondilated aortas (P<0.05). There was no significant difference in the GLS and EF between the BAV subgroups (all P values >0.05). The distributions of GWI, GCW, GWW, and GWE among the BAV subgroups are shown in *Figure 1*.

 

**Table 2** Characteristics of patients stratified by ascending aortic diameter

| Variables | Control (N=50) | BAV with nondilated aorta (N=39) | BAV with mildly dilated aorta (N=33) | BAV with moderately dilated aorta (N=32) |
|---|---|---|---|---|
| Age (years) | 46.16±9.97 | 37.15±12.23[!] | 50.58±12.01* | 51.72±7.53* |
| Men, n (%) | 32 (64.0) | 31 (79.5) | 25 (75.8) | 22 (68.8) |
| Heart rate (bpm) | 74.08±9.13 | 75.03±8.86 | 76.09±10.96 | 75.16±11.24 |
| Body surface area ($m^2$) | 1.66±0.17 | 1.64±0.13 | 1.77±0.20[!]* | 1.69±0.15 |
| Systolic blood pressure (mmHg) | 120.66±8.00 | 120.03±9.59 | 124.42±9.28 | 129.13±11.21[!]* |
| Diastolic blood pressure (mmHg) | 79.10±9.06 | 77.85±8.02 | 81.97±6.60 | 84.5±9.61[!]* |
| Hypertension, n (%) | 0 (0) | 7 (17.9)[!] | 10 (30.3)[!] | 12 (37.5)[!] |
| Interventricular septum index ($cm/m^2$) | 0.45±0.07 | 0.45±0.09 | 0.46±0.10 | 0.52±0.11[!]* |
| End-diastolic volume index ($mL/m^2$) | 55.12±16.13 | 57.24±15.25 | 61.56±12.73 | 63.07±19.71 |
| EF (%) | 65.47±1.54 | 65.32±2.03 | 65.02±1.63 | 64.82±1.36 |
| LV mass index ($g/m^2$) | 62.42±7.22 | 71.18±10.17[!] | 78.46±14.26[!] | 86.07±13.78[!]* |
| E/A | 1.22±0.21 | 1.23±0.20 | 1.17±0.19 | 1.14±0.22 |
| E/e' average | 7.03±0.94 | 7.11±1.22 | 7.13±0.82 | 7.29±1.54 |
| Ascending aortic diameters index ($cm/m^2$) | 1.87±0.21 | 1.88±0.22 | 2.16±0.26[!]* | 2.73±0.30[!]*[†] |
| Aortic stiffness index (β) | 3.97±0.36 | 3.98±0.33 | 5.12±0.83[!]* | 7.11±1.04[!]*[†] |
| GLS (%) | 22.07±0.53 | 19.62±0.93[!] | 19.50±0.83[!] | 19.10±0.94[!] |
| GWI (mmHg%) | 1,749.34±95.74 | 1,794.95±101.03 | 1,849.85±91.21[!] | 1,879.78±130.97[!]* |
| GCW (mmHg%) | 2,096.46±121.29 | 2,106.69±189.60 | 2,181.82±134.60[!] | 2,199.88±178.70[!] |
| GWW (mmHg%) | 57.64±15.74 | 79.64±20.21[!] | 97.48±23.68[!]* | 121.16±27.32[!]*[†] |
| GWE (%) | 96.92±0.75 | 95.77±0.84[!] | 95.03±0.98[!]* | 94.16±1.17[!]*[†] |

Normally distributed continuous variables are expressed as the mean ± SD. Categorical variables are expressed as absolute values and percentages. [!], P<0.05, significantly different from control; *, P<0.05, significantly different from BAV with nondilated aorta; [†], P<0.05 significantly different from BAV with mildly dilated aorta. BAV, bicuspid aortic valve; LV, left ventricular; EF, ejection fraction; E, peak early diastolic mitral flow velocity; A, late diastolic mitral inflow velocity; e', peak early diastolic mitral annular velocity; GLS, global longitudinal strain; GWI, global work index; GCW, global constructive work; GWW, global wasted work; GWE, global work efficiency.

### *Linear relationship between stiffness index and MW parameters and GLS*

The aortic stiffness index showed significant correlations with GWI, GCW, GWW, and GWE in a univariate linear analysis. In the adjusted multivariable analysis for confounding factors (age, sex, hypertension, SBP, E/A, E/e' average, LV mass index, GLS, EF), the aortic stiffness index remained an independent influencer of GWI, GCW, GWW, and GWE (*Table 3*).

The distribution of GLS and ascending aortic diameter or the aortic stiffness index is shown in *Figure 2*. There was only a weak correlation between GLS and ascending aortic diameter (r=–0.346; P=0.001) or the aortic stiffness index (r=–0.328; P<0.001).

### *Association between aortic stiffness index and ascending aortic diameter*

In the different BAV subgroups, the aortic stiffness index gradually increased with greater ascending aortic diameter (nondilated: 3.98±0.33; mildly dilated: 5.12±0.83; moderately dilated: 7.11±1.04). *Figure 3* shows the correlation between ascending aortic diameter and the aortic stiffness index (r=0.863; P<0.001), with the scattering of values.

 

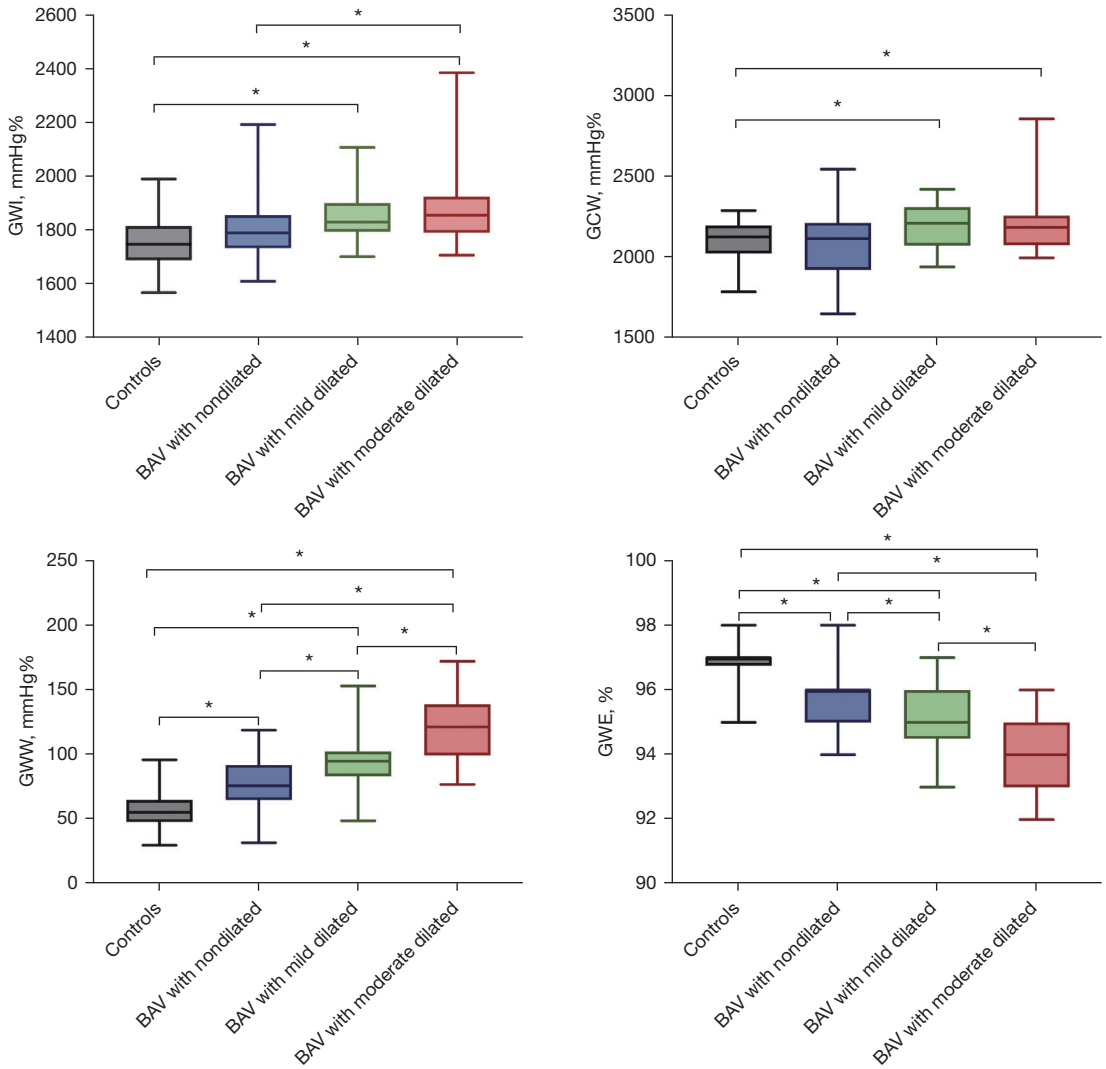


**Figure 1** Myocardial work parameters of controls and patients with BAV stratified by ascending aortic diameter. *, P<0.05. BAV, bicuspid aortic valve; GWI, global work index; GCW, global constructive work; GWW, global wasted work; GWE, global work efficiency.

**Table 3** Univariate and multivariate linear regression analysis of the aortic stiffness index for the myocardial work parameters

| Variables | Univariable | | | Multivariable* | | |
|---|---|---|---|---|---|---|
| | Standardized beta | 95% CI | P value | Standardized beta | 95% CI | P value |
| GWI | 0.20 | 0.33 to 29.32 | 0.045 | 0.25 | 2.37 to 34.73 | 0.025 |
| GCW | 0.21 | 2.00 to 46.41 | 0.033 | 0.21 | 0.07 to 48.32 | 0.049 |
| GWW | 0.54 | 7.30 to 13.68 | <0.001 | 0.37 | 3.22 to 10.99 | <0.001 |
| GWE | −0.54 | −0.56 to −0.29 | <0.001 | −0.36 | −0.45 to −0.13 | 0.001 |

Univariate linear regression analysis of the aortic stiffness index and myocardial work parameters. *, multivariate linear regression analysis was adjusted for the conventional risk factors of age, sex, hypertension, systolic blood pressure, and echocardiographic parameters related to myocardial work parameters (E/A, E/e' average, left ventricular mass index, global longitudinal strain, ejection fraction). GWI, global work index; GCW, global constructive work; GWW, global wasted work; GWE, global work efficiency; E, peak early diastolic mitral flow velocity; A, late diastolic mitral inflow velocity; e', peak early diastolic mitral annular velocity.

 

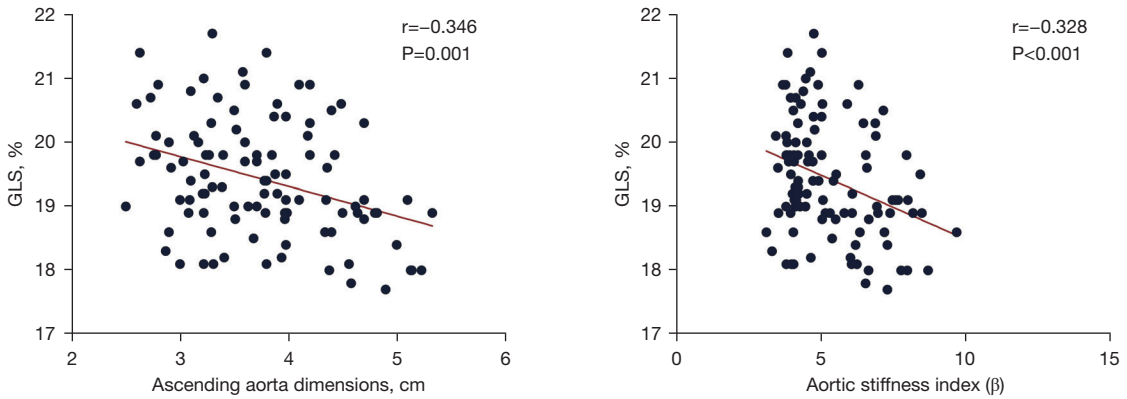


**Figure 2** The distribution between GLS and ascending aortic diameter or aortic stiffness index. GLS, global longitudinal strain.

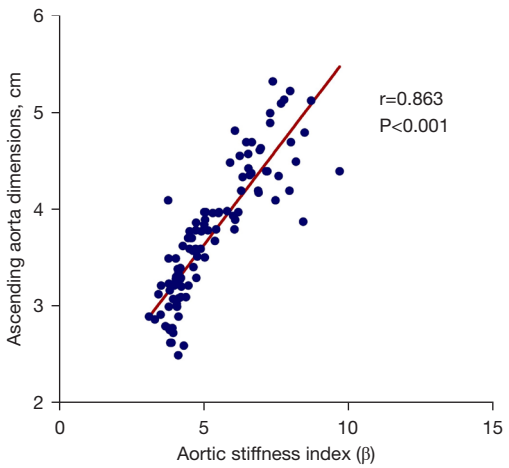


**Figure 3** Association between aortic stiffness index and ascending aortic diameter.

### *Reproducibility of GLS and MW analysis*

Both the intraobserver and interobserver ICCs of the GLS and MW parameters exhibited excellent agreement. The ICCs for interobserver reproducibility for GLS, GWI, GCW, GWW, and GWE were 0.88, 0.80, 0.90, 0.79, and 0.77, respectively; meanwhile, the ICCs for intraobserver reproducibility for GLS, GWI, GCW, GWW, and GWE were 0.91, 0.79, 0.85, 0.83, and 0.81, respectively.

## Discussion

The primary findings of the present study can be summarized as follows: (I) the total BAV population showed impaired MW parameters, GLS, and aortic stiffness index as compared with the controls; (II) as aortic dilation increased in the BAV subgroups, aortic stiffness index and GWW increased while GWE decreased, whereas GLS did not differ significantly.

Valve dysfunction and aortic lesions characterize BAV. The latter is frequently accompanied by ascending aortic dilatation and altered arterial stiffness, a major determinant of dynamic LV afterload which affects myocardial function (5). In assessing myocardial function impairment, current risk stratification is primarily based on EF and GLS (17). However, EF and GLS load dependence–related limitations may misinterpret the true myocardial performance (7,18). The noninvasive MW developed by Russell *et al.* (19) incorporates systolic, diastolic, and isovolumic components, thereby overcoming the load dependency. Moreover, noninvasive MW can allow for the evaluation of wasted MW and subsequent work efficiency (20). Studies have demonstrated that noninvasive MW is a good diagnostic and prognostic indicator in different cardiovascular diseases (21-23). However, its application in patients with BAV has yet to be well elucidated.

### *MW in patients with BAV*

In our study, patients with BAV showed increased GWI, GCW, and GWW and decreased GWE compared with controls. The higher aortic stiffness index in patients with BAV than in controls could explain these results. The aortic stiffness index, a quantitative marker of arterial stiffness, is strongly related to rapid aortic dilation and future cardiovascular events (24). In a stiffened aorta, the pressure and flow waves generated by cardiac ejection arrive earlier in systole, augmenting the afterload of the ventricles in late systole (25). Moreover, the increase in afterload can

 

cause a short-term reduction in stroke volume. Thus, the LV pump function requires additional positive MW to compensate for this, which is reflected in higher levels of GWI and GCW. In addition, a stiffened aorta places the myocardium in prolonged abnormal load conditions, and ventricular–arterial coupling is altered to maintain normal cardiac output (25). More specifically, higher myocardial energy consumption is required to dilate the stiff artery. Hence, observations of increased GWW (LV work not contributing to myocardial ejection) and decreased GWE (a composite of the severity of the myocardial injury and LV function) are not surprising in the context of arterial stiffness (26). Furthermore, increased arterial stiffness may reduce coronary perfusion and elevate myocardial oxygen demand (27), compromising LV function. An impaired myocardium can result in asynchronous contraction and postsystolic shortening, thus leading to an increase in ineffective myocardial ejection (increased GWW) and impaired work efficiency (decreased GWE) (28).

Our study additionally revealed the aortic stiffness index to an independent influencing factor of MW parameters, which persisted even after adjustment for other confounders. The results were consistent with the findings of Duan *et al.* (29), who reported there to be a significant association between increased arterial stiffness and MW parameters. From another perspective, the relationship between arterial stiffness and MW parameters may facilitate the interpretation of subclinical myocardial function impairment in patients with well-functioning BAV.

### *Adverse impact of aortic dilation on myocardial function assessed with MW*

Bicuspid aortopathy is another primary concern in the clinical management of BAV and is characterized by ascending aortic dilation and arterial stiffness. Ascending aortic dilation and arterial stiffness have been associated with an increased risk of adverse aortic and cardiovascular events (30,31). In clinical practice, the aortic stiffness index of BAV is not typically calculated, whereas the aortic diameter is routinely measured and incorporated as a reference indicator for intervention (32). This is because the aortic diameter is more accessible and enables rapid identification of the patients affected. Therefore, further research on the influence of ascending aortic dilation on MW parameters is needed. Our data showed that in the BAV subgroups with increasing aortic dilation, GWW was increased while GWE was decreased. The results indicate that cardiac energy is more poorly used for blood ejection from the LV to the aorta, further degrading myocardial function. One underlying explanation for this may be that a dilated ascending aorta exhibits increased systemic endothelial dysfunction and plasma MMP-2 levels (15,33). Activated MMP-2 could contribute to the degradation of the cellular matrix components elastin and collagen while increasing arterial stiffness (15). Aortic dilation is positively associated with increased aortic stiffness index in patients with BAV, as shown in our and other studies (13). In this regard, increased aortic dilation might indicate a rising afterload, which has a detrimental effect on myocardial function. However, controversy still exists concerning whether aortic stiffness leads to aortic dilatation. Our study only demonstrated a linear correlation between aortic dilatation and the aortic stiffness index, while the causal relationship between aortic dilatation and stiffness could not be confirmed. Therefore, the aortic stiffness index, which is merely an indicator of aortic dilatation–based impairment of myocardial function, remains a potential explanation for these results.

The study by Chan *et al.* (34) showed that as hypertension staging increases (increase in afterload), the GWI incorporating afterload also increases, whereas GLS alone does not increase. Similarly, our study found significant changes in MW parameters with greater dilatation of the ascending aortic diameter (i.e., increase in the aortic stiffness index). In contrast, GLS did not reveal the negative effect of aortic dilation on myocardial function. Interestingly, in patients with BAV and no ascending aortic dilatation, GWW increased and GWE decreased as compared with controls, although the aortic diameter and aortic stiffness index were similar. These findings offer a novel perspective of BAV as being not only a valvulo-aortopathy disease but also a form of cardiomyopathy (35,36).

### *Clinical implications and future directions*

Overall, our study expands the application of noninvasive MW—a novel method that combines myocardial deformation and afterload—to patients with well-functioning BAV and aortic dilation. The results of our study suggest that clinicians should pay close attention to patients with well-functioning BAV and aortic dilation to prevent irreversible myocardial impairment. As a next step in research, it may be worthwhile to evaluate whether interventions to reduce aortic dilation or arterial stiffness

 

could improve myocardial function and work efficiency in this population.

### *Limitations*

There were certain limitations in this study. First, as a single-center design was employed, there may be issues related to a small overall sample size or bias in the selection of study participants. Second, pulse-wave velocity is generally recognized as the gold standard for assessing systemic arterial stiffness, but it is of limited value for evaluating local arterial stiffness. However, we calculated the aortic stiffness index from the aortic diameter and blood pressure, and logarithmically adjusted the relationship between stiffness index and pressure. Consequently, the aortic stiffness index was less affected by changes in pulse pressure, affording reliable measurement of aortic mechanical properties (24). Third, the noninvasive cuffed arterial blood pressure used in MW calculation can be imprecise. Despite these potential limitations, the estimation of MW was likely accurate owing to the time integral of valvular events and the slight pressure difference (37).

## Conclusions

In patients with well-functioning BAV, as aortic dilatation increased, GWW gradually increased while GWE decreased. MW could reveal the adverse effects of aortic dilation on LV function, while GLS could not. Noninvasive MW may be of paramount value in assessing myocardial injury in this population.

## Acknowledgments

*Funding:* This work was supported by the National Natural Science Foundation of China (Nos. 82171961 and 82211530116).

## Footnote

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-294/coif). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Human Subjects Review Committee at Wuhan Union Hospital (No. UHCT22412). Individual consent for this retrospective analysis was waived.



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**Cite this article as:** Tan Y, Li Y, Shi J, Zhang Y, Huang L, Zhao R, Deng W, Liu T, Fang L, Zhang L, Xie M, Wang J. Noninvasive left ventricular pressure-strain myocardial work in patients with well-functioning bicuspid aortic valves and aortic dilation: a preliminary study. Quant Imaging Med Surg 2023;13(10):6517-6527. doi: 10.21037/qims-23-294

 