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The Association Between Left Atrial Strain and Left Ventricular Ejection Fraction in a 3D Heart Model in Patients With Severe Aortic Stenosis

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Abstract

Objectives: Aortic stenosis (AS) is a common valvular disease diagnosed in nearly 3% of adults who are older than 65 years. Echocardiography is the main modality for the diagnosis of an AS. The left atrial (LA) strain can help in a better evaluation of heart failure and predict left-side pressures. Considering that a left ventricular ejection fraction (LVEF) is an important factor for cardiologists regarding better selection of surgery treatment in these patients, the evaluation of the LA strain and LVEF, as well as their association can help physicians in a better evaluation of borderline patients who are asymptomatic with borderline LVEF.

Materials and Methods: Atrial mechanics were prospectively evaluated in 43 consecutive patients with severe AS referring to Shahid Rajaee Heart Center (Tehran, Iran), echocardiography laboratory for their regular valve disease follow-ups from July 2018 to February 2019. The LA strain, the LVEF, and their association were analyzed by a 3D heart model.

Results: The mean age of patients was 56.6±18.9 years. The LA strain did not have any association with age ($P=0.09$). In addition, no association was found among LA strains, hypertension, and smoking in patients with severe AS ($P>0.05$). Finally, the results showed that an LA strain had a significant association with a 3D method of LVEF ($P=0.02$).

Conclusions: In general, an LA longitudinal strain has a significant association with a 3D LVEF in patients with severe AS and can help physicians better evaluate patients with severe AS.

Keywords: Left atrial strain, Left ventricular ejection fraction, 3D heart model, Severe aortic stenosis

Introduction

Aortic stenosis (AS) is a prevalent valvular disease that is diagnosed in approximately 3% of adults who are older than 65 years. The gradual increase in the left ventricular (LV) after loading is compensated by an LV hypertrophy which is accompanied by increased left atrial (LA) preload (1). The onset of symptoms negatively affects patients' outcomes with an average survival of less than 3 years.

Echocardiography is the main modality for the diagnosis of an AS. It is a non-invasive, reliable method with comparable results with an invasive catheterization method and is suitable for the long-term follow-ups of patients. However, AS echocardiography occasionally yields undesirable results. When the LV ejection fraction (LVEF) decreases, a Doppler study and gradient measurement may underestimate the severity of an AS. Moreover, high gradients could be measured from a mild AS due to some confounding factors (2).

In this study, a 3D heart model was used for a better evaluation of an LVEF in patients with severe AS. Given that the LVEF is an important factor for cardiologists to select surgery treatment in these patients, a better evaluation of the LA strain and LVEF, along with their association can help physicians in a better evaluation of borderline patients who are asymptomatic with borderline LVEF.

Materials and Methods

In this cross-sectional study conducted from July 2018 to February 2019, the atrial mechanics were prospectively evaluated in 43 consecutive patients with severe AS referring to Shahid Rajaee Heart Center, echocardiography laboratory to evaluate their valvular heart disease. The patients were examined for the severity of valve stenosis such that an aortic valve area (AVA) less than 1 cm^2 (or indexed AVA <0.6 cm^2/m^2), a trans-valvular peak velocity of ≥4 m/s on continuous wave Doppler, and a mean gradient ≥40 mm Hg were used to diagnose a severe AS.

All the included patients had sinus rhythm, no concomitant valve disease other than the aortic valve, and no previous myocardial infarction. In addition, optimal image quality for endocardial border detection and speckle tracking analysis was present in all patients. The inclusion criterion was only a true severe AS defined earlier while the exclusion criteria included any arrhythmia, more than one associated heart valve disease, poor image quality

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Key Messages

- This study highlights the importance of LA strain in determining the need for surgery in pattients with severe aortic stenosis and borderline signs and symptoms.

for endocardial border detection, and speckle tracking analysis.

The patients were also evaluated in terms of their age, gender, and body surface area, as well as a history of hypercholesterolemia, diabetes mellitus, and systemic arterial hypertension.

Echocardiographic Evaluation

All patients were evaluated by an Echocardiography fellow using an EPIQ7 ultrasound machine (Philips Medical Systems). The M-mode, two-dimensional (2D), color Doppler, pulsed-wave, and continuous-wave Doppler data were recorded for offline analysis by two echocardiography specialists. The measurements were performed at least in three cardiac cycles, and the average value was calculated accordingly.

To measure the severity of an AS, the specialists used the transvalvular aortic velocity-time integral, mean pressure gradient, and peak aortic velocity during a Doppler ultrasonography. The AVA was measured using a continuity equation method, and the LVEF was derived by the 3D heart model method.

Speckle-tracking Echocardiography

The researchers A frame rate of 60-80 frames/s was employed in Speckle-tracking, 2D, and gray-scale imaging echocardiography. Then, the LA mechanics was analyzed by an EchoPAC semi-automated and 2D strain software from an apical four-chamber view when the patients were requested to have a brief breath-hold concomitant with a simultaneous electrocardiographic recording. The operator manually traced the LA endocardial borders, and longitudinal strain curves were formed for each atrial segment after segmental tracking. The peak atrial longitudinal strain (reservoir) was measured at the end of an LV systole. Eventually, average values were estimated by evaluating all 6 LA segments and the four-chamber view.

LV Ejection Fraction by Heart Model 3D Echocardiography

Our dataset was analyzed using the Q Lab advanced 'Heart Model' analysis software. The method, which was previously described by Tsang et al (3), was used in this study. This software is sensitive to endocardial surfaces and uses an adaptive algorithm. Using motion detection, the end-diastolic and systolic 3D shapes of the left ventricle cavity were employed as an algorithm to analyze ejection fraction. The software matched the information from known datasets to the current patients. Manual measurements were obtained when necessary.

Data Analysis

The continuous variables are expressed as the mean ± standard deviation and the categorical variables are presented as percentages. All patients (N = 43) with severe AS attending our center between July 2018 and February 2019 were included in this study by a convenience sampling method.

Finally, a simple linear regression analysis was applied to evaluate any association between an LA strain and an LVEF, and a two-tailed $P < 0.05$ was considered statistically significant.

Results

The mean age of patients was 56.6±18.9 years. Table 1 presents the demographic findings of the patients.

The mean interventricular septum diameter was 1.2 ± 0.2 cm, and 79% of patients had LV hypertrophy. The mean LA longitudinal strain was 13.2 ± 11.6 with a minimum of -26 and a maximum of 33.4. The LA strain demonstrated no association with age ($P = 0.09$). Moreover, no association was found among the LA strain, hypertension, and smoking in patients with severe AS ($P > 0.05$).

Figure 1 depicts LA strain measurement in patients with severe AS. A 3D method was used for measuring the LVEF in all patients. Figure 2 shows the results of the 3D heart model. The applied echocardiographic method for the 3D LVEF measurement is illustrated in Figure 3.

The results revealed that the LA strain had a significant association with the 3D method of LVEF measurement ($P = 0.02$). Figure 4 displays the LA strain distribution in patients with severe AS. Based on data in Figure 5, higher LVEF is associated with higher LA strains in patients with severe AS.

Discussion

The results showed that an LA strain had a significant association with the measured LVEF in a 3D heart model in patients with a severe AS.

AS is a common valvular disease affecting about 9.8% of those who are 80-90 years old. Its epidemiology

Table 1. Demographic and Laboratory Findings of Patients

Variable	
Smoking, No. (%)	32 (74.4)
Hyperlipidemia, No. (%)	27 (62.8)
Hypertension, No. (%)	22 (51.2)
BMI	25.8±5.1
Gender, No. (%)	
Female	13 (30.2)
Male	30 (69.8)
Creatinine	1.1±0.8
Hemoglobin	12.2±2.1

Note. BMI, body mass index.

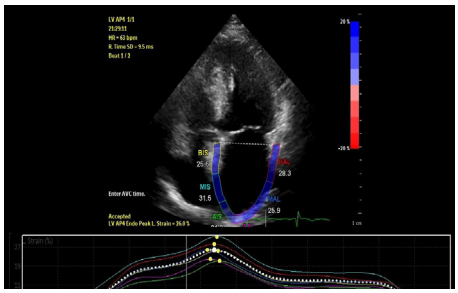

Figure 1. LA Strain Measurement in Patients With Severe AS.

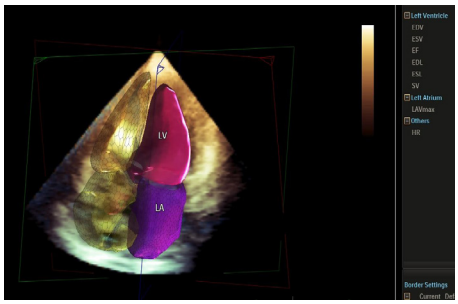

Figure 2. Measurements of the 3D heart model.

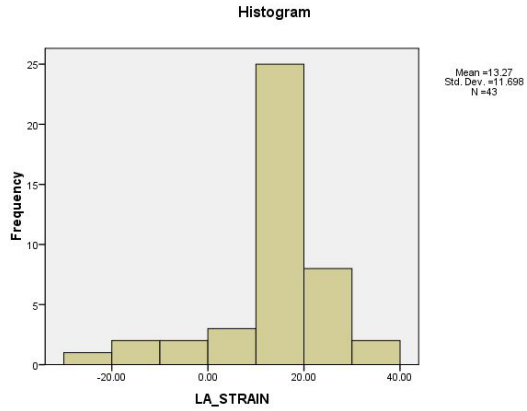

Figure 3. Applied echocardiographic method for the 3D LVEF measurement

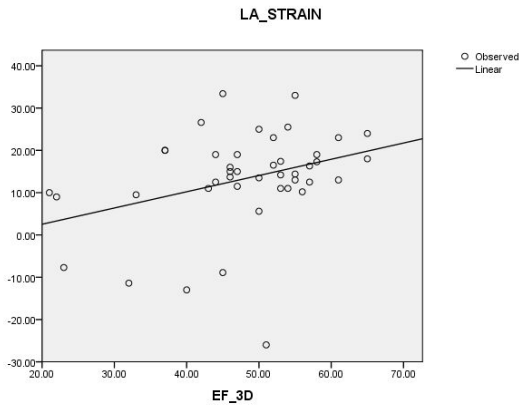

Figure 4. LA Strain Distribution in Patients With Severe AS.

in Iran is not known well. The bicuspid aortic valve, rheumatic heart disease, and senile degenerative changes are the main causes of an AS (4). Considering that an AS tends to have a progressive nature with a degenerative calcified phenomenon and due to an atherosclerotic-like process or genetic and hemodynamic factors, risk factors such as hypertension, metabolic syndrome, and even diabetes mellitus and smoking aggravate the AS progression (5). On the other hand, compensatory mechanisms such as LV hypertrophy postpone the onset of symptoms. Finally, these compensatory processes fail to keep patients asymptomatic, leading to the initiation of dyspnea, angina, and syncope attacks (1,6). Some patients with severe AS restrict their activity and although their exercise capacities are diminished, they seem to be asymptomatic. However, they are at an increased risk of serious comorbidities such as sudden death (7). Although an exercise test can be implemented for these patients, the novel echocardiographic method of the LA strain study has opened a new perspective for a better evaluation of patients. The LA strain can help in a better evaluation of heart failure and prediction of the left-side pressures, exercise performance, as well as a better evaluation of patients' outcomes, and early morbidity and mortality of patients with structural heart diseases (8).

Timely surgical valve replacement improves a patient's outcome. Asymptomatic patients with severe AS are a difficult group in decision-making. Given surgery complications and the need for warfarin therapy and its comorbidities, cardiologists attempt to postpone valve replacement until it is necessary. On the other hand, the possible sudden cardiac death in asymptomatic patients reveals the importance of administrating proper modalities for early diagnosis of any tissue damage in both left atrium and left ventricle in addition to the increasing surgery morbidity and mortality with progressive damage to LV contractile force in a severe AS (9, 10).

The LA function is associated with LV filling pressures in asymptomatic patients with an AS (11, 12). A few studies have investigated an LA strain and its association with an LVEF in patients with severe AS. Telles et al found that an LA pump dysfunction was associated with abnormal exercise hemodynamics in a heart failure with a preserved LVEF (13). In another study, a 3D method was as good as a trance esophageal echocardiography in the evaluation of the severity and anatomy of an aortic valve in patients with AS (14). Likewise, Mateescu et al reported that the LA longitudinal strain was lower in symptomatic patients in patients with severe AS. They further suggested that the evaluation of an LA function by speckle-tracking could be a useful method for the risk stratification of patients with AS (15). An LA enlargement had no good association with its function in patients with AS thus an LA function and its strain study could give additional and valuable

prognostic information in making decisions about the patients' treatment (16). In their study, Pessoa-Amorim et al evaluated 114 patients without atrial fibrillation (AF) who were candidates for aortic valve replacement because of their severe AS. An AF was observed in 36 patients and an LA strain could predict the AF independent of the LA volume (17). In this study, although an LA longitudinal strain had a significant association with the LV end diastolic and systolic diameters, no association was found between a longitudinal strain and an LV ejection fraction.

Contrary to their study, our results demonstrated a significant association between an LVEF and an LA strain, and the LVEF was measured with a 3D heart model in this study. Meanwhile, a 3D echo was used in the current study, which is less affected by confounding factors. Meimoun et al studied 102 patients with moderate to severe AS and showed that an LA strain was an independent predictor of an LV diastolic and systolic dysfunction and had a significant association with AS severity (18), which is in line with the findings of the present study.

Al Saikhan et al concluded that the LA phasic function was significantly worse in patients with a heart failure with a mid-range ejection fraction compared to those with a heart failure with a preserved ejection fraction. However, an LA size was similar between these groups. Hence, it seems that an LA strain can be a better predictor of a moderate LV dysfunction which is an indication for a valve replacement therapy in asymptomatic AS patients (19), which corroborates with the results of this study.

Considering a significant decrease in the survival of AS patients after the onset of symptoms and the above-mentioned life-threatening conditions, as well as the sensitivity of LA strain studies in the early prediction of serious cardiac damage and heart failure, it is suggested to use an LA strain, especially in those with borderline findings for valve surgery in addition to those with nonspecific symptoms such as mild dizziness in order to reduce the mortality and morbidity of patients before and after aortic valve replacement.

An LA strain and a 3D echocardiography are new noninvasive methods and can give additional information for a better evaluation of patients, and we can find their indications in our daily practice with further studies.

Limitations

Our study was conducted on symptomatic patients. It is advisable to perform another study on asymptomatic patients in order to better evaluate the relationship between an LA strain and an LVEF.

Conclusions

Overall, an LA longitudinal strain has a significant association with an LVEF in a 3D heart model in patients with severe AS and can help physicians in a better evaluation of patients with severe AS.

Authors' Contribution

All listed authors have equally contributed to the project.

Conflict of Interests

The authors declare that they have no competing interests.

Ethical Issues

This manuscript is a part of an echocardiography fellowship thesis. The study protocol was approved by the Ethics Committee of Iran University of Medical Sciences (Code number: IR.RHC.REC 1397.054).

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