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ECHOCARDIOGRAPHIC ASSESSMENT OF RIGHT ATRIUM DEFORMATION INDICES IN HEALTHY YOUNG SUBJECTS

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Abstract

In recent past, the assessment of the atrial motion and deformation indices gained through DMI Doppler Myocardial Imaging has been projected such as fresh approach of discovering the atrial function.

In this study the basic aim was to analyze the RA right atrial regional function using myocardial velocities, strain, and strain rate imaging (SRI) and compare it with the function of the inter-atrial septum (IAS) and left atrial (LA) lateral wall in healthy young adults.

Overall 75 healthy young individuals (35 women and 40 men) underwent standard transthoracic echocardiography and DMI at rest. Myocardial velocities, strain, and SRI profiles from the RIGHT ATRIAL free wall, IAS, and LA lateral wall were calculated throughout the three cardiac cycles. Diastolic, peak systolic and peak time were resultant, and the average of the 3 cardiac cycles was taken into account for analysis in this study.

The RIGHT ATRIAL peak systolic, peak of early, and late diastolic velocities were 9.2±1.6 cm/s, -9.5±1.8 cm/s, and -8.3±2.1 cm/s, respectively. The RIGHT ATRIAL peak systolic strain was 152% ± 51%. The RIGHT ATRIAL systolic strain was significantly higher than that of the IAS (87%±21%, P = 0.001) and the LA lateral wall (89%±15%, P = 0.001). The RIGHT ATRIAL peak systolic, peak early and late diastolic SR were 6.3±3.0 s-1, -5.4±1.7 s-1, and -4.5±2.2 s-1, respectively.

DMI proved to be a feasible and reproducible approach for the assessment of the RIGHT ATRIAL function in healthy young subjects. Study of myocardial properties showed that the RIGHT ATRIAL free wall myocardial motion and deformation were significantly higher than those of the IAS and the LA lateral wall, but the rate of the RIGHT ATRIAL free wall deformation was not significantly higher than that of the IAS and the LA lateral wall.

Keywords: *Strain Rate, Right Atrium; Normal Values; Strain, Velocity; Strain*

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INTRODUCTION:

William Harvey was the first to identify the atrium as a receptacle storehouse and reported that the RIGHT ATRIAL was the first to live, and the last to die. Accordingly, the right atrium (RIGHT ATRIAL) is a dynamic structure with complex mechanics. Ideally, the RIGHT ATRIAL should transfer a high volume of blood to the right ventricle (RV) rapidly at low pressure to prevent from peripheral edema and hepatic congestion. Active and passive assessment of atrial functions is a vital component in the assessment of the function of cardiac and is significant to treatment and diagnosis of patients with primarily or secondarily affected atrial function (Centella et al., 2016).

In recent past, the atrial motion regional assessment and deformation properties obtained via Doppler-derived velocity and SRI strain rate imaging has been proposed as a new approach for the exploration of the atrial function. Strain Rate Imagining is measured from the regional velocity gradients within the sample volume aligned with the Doppler beam. Strain rate (SR) measures the rate of the myocardial deformation, and peak systolic SR and diastolic SR represent the magnitude of the peak deformation rate in systole and diastole. Strain is obtained through integrating SR and represents the deformation of the myocardium over time, and end-systolic strain represents the magnitude of peak deformation in systole (D'Alto et al., 2016).

Deformation and motion both are significant functions of the LV left ventricular performance, but study of the atrial function through echocardiography has not yet been fully established. DMI has been employed as a promising approach to quantify the regional myocardial function as a sensitive and reproducible tool in healthy subjects as well as in several diseases involving the atria. But using this approach in the assessment of the RA deformational function is not a common practice. In most of the studies which hitherto carried out the evaluation the left atrial (LA) function, there is currently a lack of data on the evaluation of the RA function via SRI (Hetyey, Vörös and Reiczigel, 2017).

OBJECTIVE:

According to this study, we sought to determine the normal values of the myocardial velocities, strain, and SRI of the RA free wall in healthy young adults and compare them with those of the inter-atrial septum (IAS) and the LA lateral wall.

METHODS:

Patients

A total of 75 healthy young individuals (age = 15-40 years old, mean age = 29±14 years; 35 women and 40 men) underwent standard transthoracic echocardiography (TTE) at rest. All the patients had unremarkable clinical history and normal findings on physical examination, ECG, and baseline echocardiography, and none of them was taking cardiac medications. The mean of heart rate was 67±14 bpm.

Echocardiography

Standard TTE study was performed with a GE Vivid 07 scanner equipped with an M3S multi-frequency phased array transducer and tissue Doppler imaging facility. Data were acquired with the subjects at rest, lying in the lateral supine position. Grey-scale images were obtained using second-harmonic imaging (1.7/3.4 MHz). Two-dimensional ECG was superimposed on the images, and end-diastole was considered at the peak R-wave of the ECG. The left ventricular ejection fraction (LVEF) was measured using the Simpson's biplane approach by measuring the end-diastolic and end-systolic volumes in 2D images. Measurements of the LV and LA dimensions were made in accordance with the American Society of Echocardiography (ASE) recommendations. The ratio between peak early (E) and late (A) diastolic LV filling velocities and E wave deceleration time was determined using standard Doppler imaging. The timings of the mitral and aortic valve opening and closure were defined using pulsed wave Doppler tracings of the mitral inflow and the LV outflow.

Doppler Myocardial Imaging and Offline Analysis

Color DMI was performed using standard transthoracic apical four-chamber views according to the guidelines of the ASE, and the raw data were recorded at a depth of 16 cm, frequency of 2.4 MHz, and high frame rates of 140-170 frames/s throughout the three cardiac cycles and stored digitally in cine-loop format on the memory of the scanner. To obtain regional myocardial velocity, strain, and SR, off-line analysis was performed using the quantitative analysis software (EchoPac, General Electric Imaging System) (Hetyey, Vörös and Reiczigel, 2017).

Because of the thin atrial walls, three digital 2-mm sample volumes were placed within the mid portion of the RA free wall, IAS, and LA lateral walls; and the profiles were acquired over the three cardiac cycles. Peak systolic, early and late diastolic velocities, peak systolic strain, peak systolic, early and late diastolic strain rates were derived and subsequently averaged to obtain mean values. End-diastole and end-systole were defined to be at the electrocardiographic R peak and at the end of the electrocardiographic T-wave, respectively.

Time to peak strain and SR were calculated from the beginning of Qwave to the peak of systolic strain and early diastolic SR. The echocardiographic analyses were performed by an experienced observer, and all the Doppler data were measured at end-expiration. Intra-observer and inter-observer variability were assessed separately for the calculated indices. For the assessment of the intra-observer variability, the analyses were repeated twice by the same observer within two weeks. For the assessment of the inter-observer variability, a second independent observer repeated the analyses (Jaiv, 2016).

Statistical Analysis

All the constant variables are expressed as mean ± standard deviation (SD). The normal distribution was tested using the Kolmogorov-Smirnov (K-S) test. The constant variables were compared with the independent samples t-test or ANOVA. The Post-Hoc least significant differences (LSD) test was used for multiple comparisons. P-values $\leq$ 0.05 were considered statistically significant. The reproducibility was obtained for the analysis of the peak systolic velocity, strain and strain rate values from 20 randomly chosen subjects by two independent observers and repeated measurement of these parameters at another occasion. The intra-observer and inter-observer variability were the differences between the measurements expressed as an error percentage of the means. All the statistical analyses were performed using the SPSS v. 16 for Windows (Kasper et al., 2017).

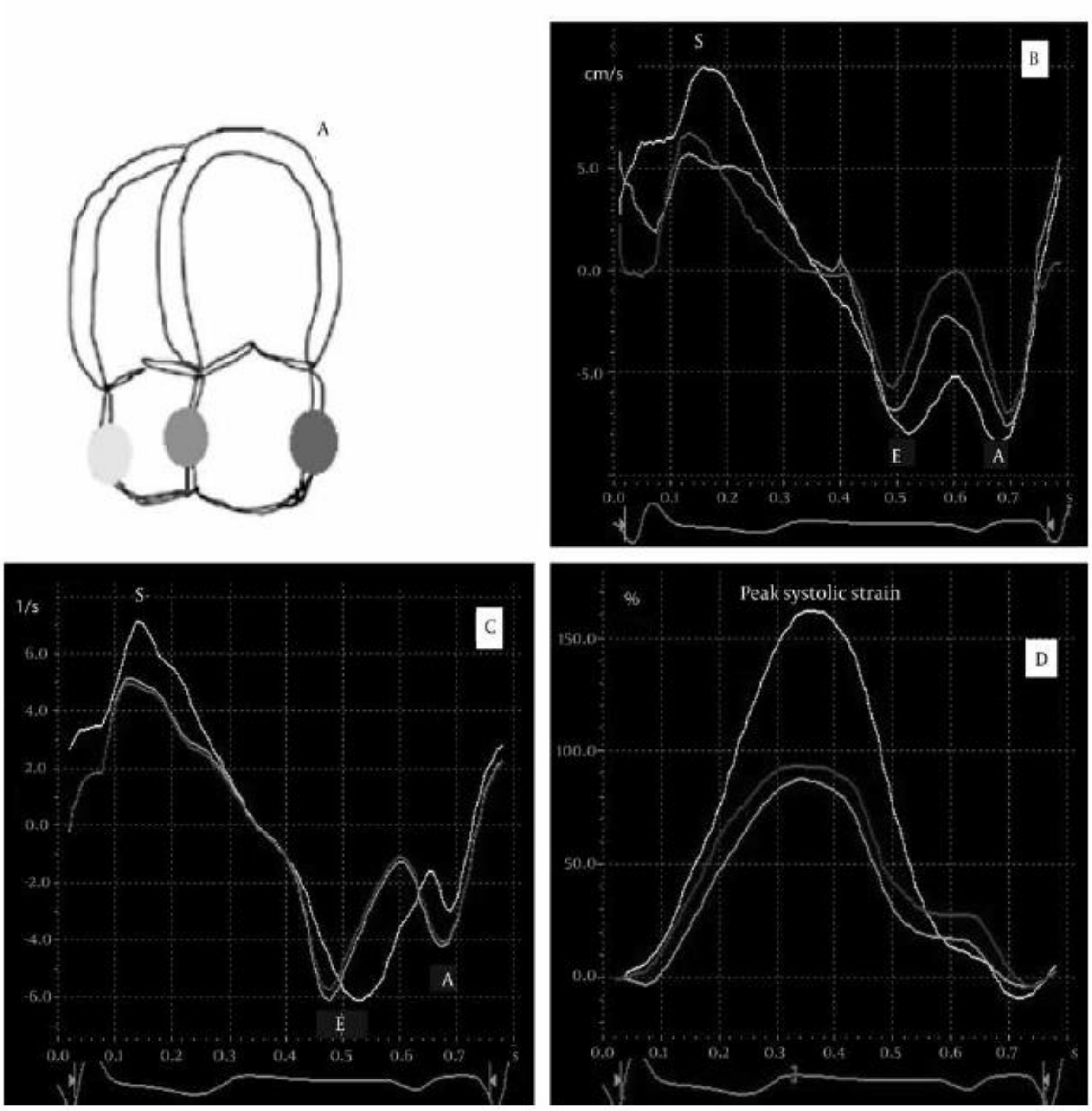

Figure 1. Velocity (B), strain (D) and strain rate (C) profiles calculated by tracking a DMI data set for the mid portion of the RA free wall (yellow), IAS (green), and LA lateral wall (red)

(Source: (Kasper et al., 2017)

RESULTS:

The general characteristics of the study population are presented in Table 1.

Echocardiographic Assessment of Right Atrium Deformation

Table 1. General Characteristics of the Study Population

Variable	Value (n = 75)
Age, year [b]	29 ± 14
Gender, Female, No. (%)	35 (46.7)
Height, cm	164 ± 9
Weight, kg	69 ± 8
Body surface area, m^2	1.78 ± 0.65
Systolic blood pressure, mmHg	120.0 ± 10.7
Diastolic blood pressure, mmHg	77.3 ± 5.2
Heart rate, bpm	67 ± 14
End-diastolic LV[a] diameter, mm	44.3 ± 5.2
End-systolic LV diameter, mm	27.2 ± 4.2
LV ejection fraction	60 ± 5
RV Sm[a], cm/s	13 ± 2
TAPSE[a], mm	25 ± 3
Left atrial diameter, mm,	28.6 ± 4.8
Left atrial area, m^2	14.3 ± 3.5
Mitral E/A ratio	1.67 ± 0.4
Deceleration time, ms	275.3 ± 55.0
Right atrial diameter, mm	22.2 ± 5.2
Right atrial maximal volume, ml	32.2 ± 11.0

[a] Abbreviations: LV, left ventricular; RV Sm, myocardial systolic velocity of RV free wall; TAPSE, tricuspid annular plane systolic excursion
b All the data are shown with mean ± SD

(Source: Leong et al., 2017)

RA Free Wall Systolic and Diastolic Velocities Compared With IAS and LA Lateral Wall Values

The RA peak systolic, peak early and late diastolic velocities were 9.2±1.6 cm/s, -9.5±1.8 cm/s, and -8.3±2.1 cm/s, respectively; there were no significant differences between the absolute value of them (P > 0.05). The RA systolic velocity was significantly higher than that of the IAS (9.2 ±1.6 cm/s vs. 6.7±2.0 cm/s, P = 0.041) and the LA lateral wall (9.2±1.6 cm/s vs. 7.1±1.2 cm/s, P = 0.048). The RA early diastolic velocity was not significantly higher than that of the IAS (-9.5±1.8 cm/s vs. -8.2±3.0 cm/s, P = 0.084), but it was significantly higher than that of the LA lateral wall (-9.5±1.8 cm/s vs. -4.9±2.1 cm/s, P = 0.044). In addition, the RA late diastolic velocity was not significantly higher than that of the IAS (-8.3±2.1 cm/s vs. -7.1±2.0 cm/s, P = 0.197), but it was significantly higher than the LA lateral wall late diastolic velocity (-8.3±2.1cm/s vs. -6.2±1.6 cm/s, P = 0.039) (Leong et al., 2017).

RA Free Wall Systolic Strain and SR Compared With IAS and La Free Wall Values

The RA peak systolic strain was 152% ±51%. The RA systolic strain was significantly higher than that of the IAS (152%±51% vs. 87%±21%, P = 0.001) and the LA lateral wall (152%±51% vs. 89%±15%, P = 0.001). The RA peak systolic, peak early and late diastolic SR were 6.3±3.0 s-1, -5.4±1.7 s-1 and -4.5±2.2 s-1, respectively; there were significant differences between the absolute value of them (P < 0.05) (Lindstrom, 2017).

The RA peak systolic SR was significantly higher than RA late diastolic SR (P < 0.05). The RA systolic SR was not significantly higher than the IAS (6.3±3.0 s-1 vs. 4.9±2.3 s-1, P = 0.147) and the LA lateral wall systolic SR (6.3±3.0 s-1 vs. 5.6±3.4 s-1, P = 0.312). Also, the RA early diastolic SR was not significantly higher than the IAS (-5.4±1.7 s-1 vs. -4.8±1.8 s-1, P = 0.223) and the LA lateral wall early diastolic SR (-5.4±1.7 s-1 vs. -4.9±2.1 s-1, P = .518). Moreover, the RA late diastolic SR was not significantly higher than the IAS (-4.5±2.2 s-1 vs. -4.1±1.9 s-1, P = 0.603) and the LA lateral wall SR (-4.5±2.2 s-1 vs. -4.0±1.6 s-1, P = .311) (Lindstrom, 2017).

Time to Peak Systolic Strain and Strain Rate

Time to peak systolic strain and SR were defined by calculating the time to reach peak systolic strain and SR for each of the RA free wall, IAS, and LV lateral wall and correcting the times by the Bazett formula. There were no significant differences between the RA free wall and IAS in terms of time to peak strain; there were, however, significant differences with respect to time to peak strain rate (353±31 ms vs. 371±32 ms, P = 0.056 and 182±33 ms vs. 248±32 ms, P = 0.01 for time to peak strain and time to peak strain rate, respectively). Furthermore, there were significant differences between the RA free wall and the LA lateral wall data (352±30 ms vs. 391±27 ms, P = 0.02 and 182±26 ms vs. 257±32 ms, P = 0.002 for time to peak strain and strain rate, respectively (Lindstrom, 2017).

DISCUSSION:

In this study, we assessed the longitudinal velocity, strain and SR values and time to peaks in the RA free wall segment using tissue Doppler and SRI and thereafter compared the data with those measured in the IAS and the LA lateral wall. The RA function plays an significant role in maintaining the cardiac function because it serves as a reservoir, conduit, and booster jump to the RV. In the reservoir function, the closure of the tricuspid valve is followed by the storage of blood; and the opening of the valve leads releasing the stored blood (Leong et al., 2017).

In the conduit function, when the tricuspid valve is open, passive blood is transferred directly from the coronary and systemic veins into the RV. And in the booster pump function, the atrium contracts and ventricular filling completes in late diastole. In this study, the three above-mentioned components of the RA function were assessed via Doppler-derived motion and deformation parameters in healthy young adults. It deserves to note that the strain curve evaluated through the Doppler approach is very compatible with the RA physiology. During the period of the RA reservoir (which corresponds to the phase of the RV systole), the RA strain increases and thus reaches a peak at the end of the RA filling just before the opening of the tricuspid valve (Leong et al., 2017).

The RA strain rate can also represent the RA reservoir function, and the measurement of changes in the atrial SR during passive atrial filling could potentially provide an index of atrial compliance. During the reservoir phase, the atrial myocardium stores elastic energy released due to opening of the tricuspid valve to aid early ventricular filling. The velocity of this spring like function of the myocardium can be demonstrated by the RA strain rate. During the opening of the tricuspid valve and the early rapid filling phase, the RA strain decreases and early diastolic SR appears in the strain rate curve, which reaches a negative peak before atrial contraction (booster phase). During the booster phase, the RA strain rate curve shows the second negative peak at the end of the RA contraction (Kasper et al., 2017).

Therefore, measurement of the RA strain and SR may represent a relatively rapid and easy-to-perform approach for the assessment of the RA function and may be clinically significant in case of a number of pathophysiological conditions associated with an abnormal RA function, e.g. valvular heart diseases, supraventricular arrhythmias, pulmonary hypertension, heart failure, and cardiomyopathies. It has been suggested that in healthy subjects, the RA free wall has the highest late diastolic velocity and late diastolic SR compared with the IAS and LA free wall (Kasper et al., 2017).

CONCLUSION:

In the study, peak systolic velocity in healthy young subjects (29±14 years old) was the highest at the RA, followed by the LA, and the lowest was at the IAS. Also, peak early and late diastolic velocities were the highest at the RA, but there were no significant differences between the IAS and LA lateral wall. Therefore, the RA free wall had higher mobility compared to LA and IAS. According to the previous studies, the IAS is placed between the two atria and its movement is thus dependent on the function of both atria and the measurement of its deformational properties may be an average of the right and left sides. In the present study, peak systolic strain was the highest at the RA compared to the IAS and LA. However, systolic SR and diastolic SR were not statistically different among the three walls. The IAS and LA motion and deformation properties were less than those of the right one. It might be explained that in normal conditions, the right side of the heart acts as a very low resistance system and the RA, with higher pectinate muscle masses, has to transfer a high volume of blood rapidly to the RV in order to prevent from peripheral edema and liver congestion. Consequently, it has to work harder than the LA, leads to the higher strain and velocity of the RA myocardium.

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