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Four-Dimensional Echocardiographic Volumetric and Functional Assessment of the Left Atrium in Healthy Male Subjects in Relation to Age

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ABSTRACT

Background: Four-dimensional echocardiography technique results in marked improvements in terms of quality and accuracy in assessing the size and function of heart chambers, especially the left atrium as its geometric variation has a notable impact on the results when using traditional echocardiographic techniques alone. Thus, this study aimed at investigating the probability of significant functional and morphological changes in the left atrium with advancing age using Four-dimension echocardiography.

Method: Four-dimensional technique derived left atrial phasic volumes and functions were assessed in (30) healthy subjects with mean age of 73.6 (±3.6) years and (30) young subjects with mean age of 23.17 (±3.5) years.

Results: Old age group showed a significant increase in maximum left atrial volume index, minimum left atrial volume index and pre-atrial contraction left atrial volume index compared to young age group (31.52±1.09 vs. 26.44±1.03, $P < 0.001$), (17.93±0.43 vs. 15.89±0.44, $P < 0.00$) and (25.73±1.003 vs. 22.34±0.77, $P < 0.01$), respectively. In the old age group, the passive left atrial emptying function (LAEF) significantly decreased (20.43±0.25% vs. 24.96±0.93%, $p<0.00$), while the active LAEF significantly increased (37.36±1.33% vs. 32.65±1.13%, P< 0.009) in comparison to the values of the young subjects.

Conclusions: These results suggest that left atrial structural as well as functional changes occur with advancing age in absence of evident pathological causes and 4-dimentional echocardiography can be used to evaluate these changes.

Keywords: Four-dimensional echocardiography, Atrial volume, Atrial function.

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Abbreviation: LA: left atrium, LV: left ventricle; 4D: four dimensional, 3D: three dimensional, LAVI: left atrium volume index, LAEF: left atrium emptying function, BSA: body surface area, Pre-AC: pre-atrial contraction, FR: frame rate.

INTRODUCTION

Diastolic dysfunction and ventricular stiffness are associated with aging process (Redfield, Jacobsen, Borlaug, Rodeheffer, & Kass, 2005). It is important to evaluate left atrial function as well as its size as they are considered good predictors of cardiovascular outcomes (Hirose et al., 2012). More recently, 4D-echocardiography had been used to assess the size and function of LA. This is because 4D-echocardiography technique outperformed 2D-echocardiography in terms of giving more precise results. In this concern, 2D-echocardiography technique assumes that the LA geometry is unchanging (de Isla et al., 2009). Recent reports documented that three-dimensional (3D) echocardiography is more dependable than 3D-computed tomography (CT) (Avelar et al., 2010; Nagaya et al., 2013). Hence, this study aimed at using 4D-echocardiography technique to illustrate the possible LA changes that occur with advancing age.

Methods

Two groups with matched body surface area (BSA) were involved in this study. Group A consisted of 30 subjects (with mean age of 73.6 (±3.6) years, mean BSA of 1.58 (±0.22) m^2). Group B consisted of 30 subjects (with mean age of 23.17 (±3.5) years, mean BSA of 1.67(±0.24) m^2). All subjects were subjected to thorough medical history and physical examination to exclude other conditions (hypertension, lung disease and diabetes) that might affect the studied parameters. The presence of arrhythmia as in atrial fibrillation, a paced rhythm, and valvular heart disease were also considered as exclusion criteria. 4D-echocardiography machine (Vivid, E9, USA) with 4V probe were used. This could result in a time–volume curve of the left atrium. A FR of 30–40 frames/second was used (Fig. 1). Electrocardiogram (ECG) was connected to each participant. Recall a full volume image and then LA volume quantification were carried out by proper alignment of view in apical two, three and four chamber views. Several marks were set on the endocardial border of LA in the apical two, three and four chamber view. Automatic tracing of LA endocardium with manual adjustment for proper tracing was then performed. After that, automatic tracking and analysis of wall motion within entire cardiac cycle was performed. LA phasic function could be measured from time–LA volume curves during sinus rhythm.

LA total emptying function (EF) (reservoir function) was defined as "(maximum LA volume – minimum LA volume)/ maximum LA volume × 100%. LA passive EF (conduit function) was defined as (maximum LA volume – pre-atrial contraction LA volume)/ maximum LA volume × 100%. LA active EF was defined as (pre-atrial contraction LA volume – minimum LA volume)/ pre-atrial contraction LA volume × 100%" (Hoit, 2014; Kowallick et al., 2014; Vianna-Pinton et al., 2009). LA volume was indexed to body surface area. The Ethics Committee of our institution has approved this study. Additionally, a written consent was taken from all participants before participation.

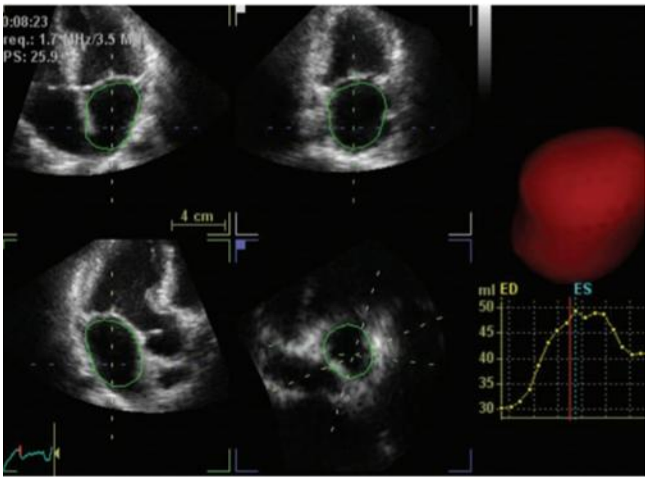

Figure 1. Four-dimensional echocardiography and time–left atrial volume curve during one cardiac cycle

Statistical analysis

Calculations of mean and standard error of mean were done for the parameters of interest. The groups under study were compared by employing independent T-test. The value of probability (*P*) of <0.05 was regarded as significant at (α=0.05). A linear regression test was conducted to define the correlation between different parameters of echocardiography and age. The statistical analysis was performed by utilizing IBM SPSS 18 software.

Results

Results of this study showed that elderly individuals (group A) had significantly higher maximum LA volume index (*P*<0.00), higher minimum LA volume index (*P*<0.00) and higher pre-atrial contraction LA volume index (*p*<0.01) than the younger age group (group B) (table 1). Passive LA emptying function was significantly lower (*P* < 0.00) in group A compared to group B, while active LA emptying function was statistically higher in group A (table 2). Linear correlation regression test showed positive linear correlation of maximum, minimum LA volume and active LA emptying function with age in the two groups (figures 2, 3 & 4); while negative correlation was documented between age and passive LA emptying function (figure 5).

Table 1. The values of maximum LAVI, minimum LAVI and Pre-AC LAVI according to study groups

	Group A N: 30 Age:73.6±3.6 BSA (m2): 1.58±0.22	Group B N: 30 Age:23.17±3.5 BSA (m2): 1.67±0.24	*P* value
Maximum LAVI, ml/m2	31.52±1.09	26.44±1.03	0.001
Minimum LAVI, ml/m2	17.93±0.43	15.89±0.44	0.00
Pre-AC LAVI, ml/m2	25.73±1.003	22.34±0.77	0.01

Data are presented as mean ± SEM. BSA; body surface area, LAVI; left atrium volume index, Pre-AC; pre atrial contration.

Table 2. The passive LAEF and active LAEF according to study groups

	Group A N: 30 Age:73.6±3.6 BSA (m2): 1.58±0.22	Group B N: 30 Age:23.17±3.5 BSA (m2): 1.67±0.24	*P* value
Passive LAEF, %	20.43±0.25	24.96±0.93	0.00
Active LAEF, %	37.36±1.33	32.65±1.13	0.009

Data are presented as mean ± SEM. BSA; body surface area, LAEF; left atrium emptying function

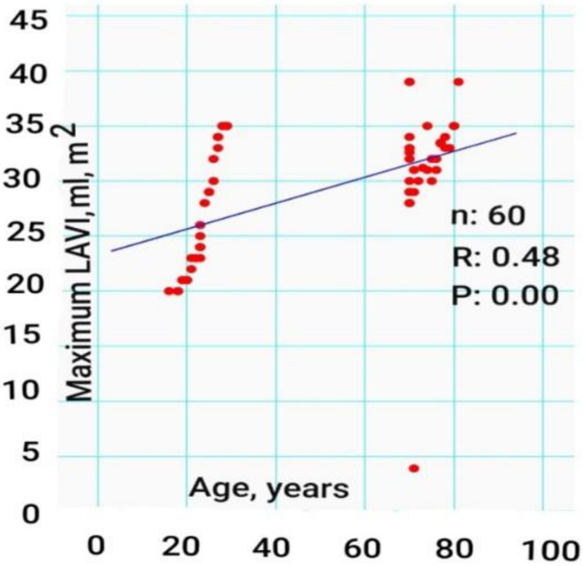

Figure 2. linear regression plot of age in (years) and maximum left atrial volume index (Max LAVI) in (ml/ml^2)

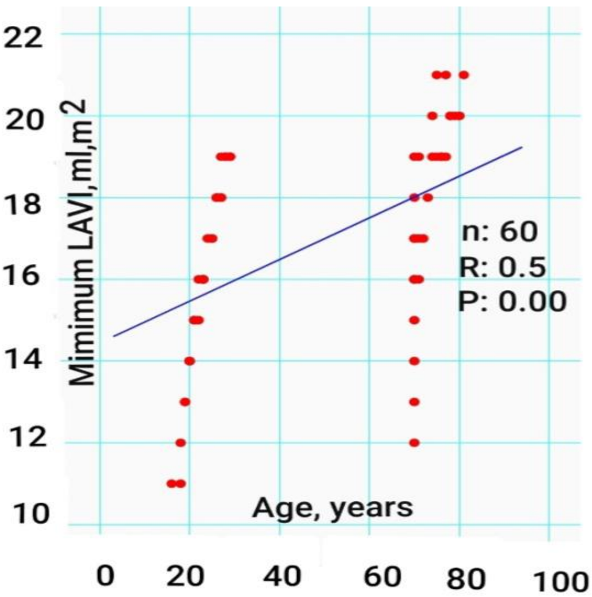

Figure 3. linear regression plot of age in (years) and minimum left atrial volume index (Min LAVI) in (ml/ml^2)

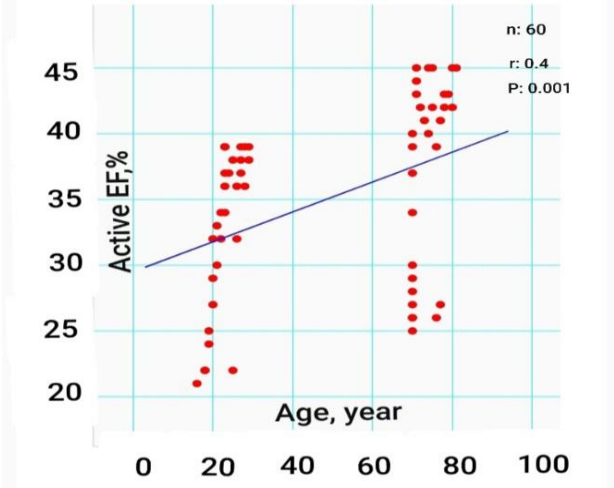

Figure 4. linear regression plot of age in (years) and active emptying function (EF %)

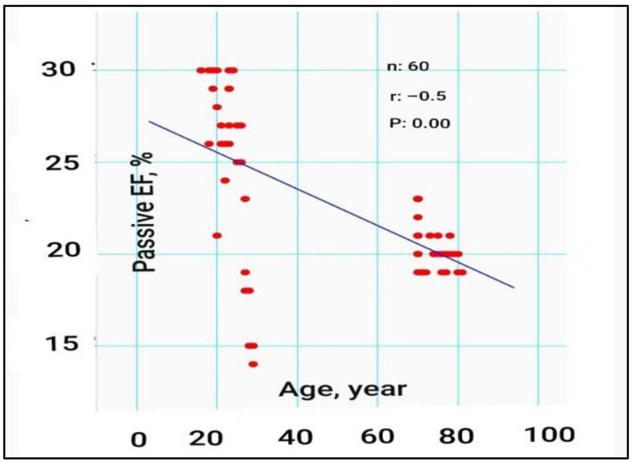

Figure 5. linear regression plot of age in (years) and passive emptying function (EF %)

Discussion

The development of 4D-echocardiographic technique is considered a major development in the field of echocardiography. It allows more accurate assessment of volumes and functions of cardiac chambers than previous methods (Kawaguchi, 2008; Seo et al., 2009; Takeguchi, Nishimura, Abe, Ohuchi, & Kawagishi, 2010). Emphasizing this fact, there has been an increasing number of studies utilizing the technique to evaluate the phasic volume and function of LA as the main investigative tool (Kawai et al., 2004; Warita, 2012). In this concern, (Rohner et al. 2011) reported a good correlation between 3D-echocardiography and cardiac CT imaging in the volumes of LA and LAEF calculations ($r = 0.92$ and $r = 0.82$, $p < 0.001$, respectively). Yet, according to the researchers' knowledge, no study has been conducted to evaluate the validity and accuracy of 4D-echocardiography when measuring the volume and function of LA.

There is rising evidence that the evaluation of the enlargement and functional impairment of LA by using echocardiography predicted significant cardiovascular consequences with high accuracy (Moller et al., 2003). Hence, 3D-echocardiography gives proper evaluation of the volume and function of LA than 2D-echocardiography by utilizing 3D-CT as a gold standard (Nagaya et al., 2013). In the current study, the assessment of the volume and function of LA was performed by using 4D-echocardiography. The use of 4D-echocardiography allows the evaluation of the features that are affected by aging process.

It is proposed that the increase in the maximum volume of LA represents the morphological marker of LV diastolic dysfunction since its diastolic pressure is directly exerted on LA phasic volumes (Tsang, Barnes, Gersh, Bailey, & Seward, 2002).

When LV relaxation becomes abnormal, the conduit function reduces with the increase in the booster pumping of LA (Spencer et al., 2001). Because the filling pressure of LV gradually rises with the progression of diastolic dysfunction, LA functions largely as a conduit (Hirose et al., 2012). The result found in the current study shows agreement with those found in the study of (Aurigemma et al. 2009) that the volume of LA increases with age.

(Boyd, Schiller, Leung, Ross, & Thomas 2011) reported changes in LA volumes with age in a larger study. They demonstrated that LA volume index increases by 0.05 ml/m^2 yearly. On the other hand, (D'Andrea et al. 2013) revealed that the size of LA differs with age, but it is considerably larger only in persons aged 50 years and older.

Those reports, however, employed traditional 2D-echocardiographic measures rather than the more advanced 4D-echocardiographic ones employed by the current study. This study found that elderly people have LAEF that is significantly greater than in young people. Concerning the passive LAEF, it was found that elderly people have significantly lower values than the young people. Moreover, (Boyd, Richards, Marwick, & Thomas 2011) and (Sun et al. 2013) revealed increase in the atrial contractile function with advancing age. However, only few studies stated no significant differences among different age groups.

Conclusions

Left atrial structural as well as functional changes occur with advancing age in absence of evident pathological causes and 4-dimentional echocardiography can be used to evaluate these changes.

Limitations

It was difficult to obtain a large number of healthy individuals, especially after age of 70 as most people in this age group have chronic medical diseases. Also, image quality posed a problem with older age group because 4D-echocardiography needs good image resolution for proper border delineation.

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