Relationship Between Left Atrial and Left Ventricular Function in Hypertrophic Cardiomyopathy: A Real-time 3-Dimensional Echocardiographic Study

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Background: **Left atrium (LA) in patients with hypertrophic cardiomyopathy (HC) has been known to have an increased size and decreased contractile function. The purpose of this study was to investigate LA and left ventricular (LV) volume change and function with real-time 3-dimensional (3D) echocardiography and to investigate association between LA and LV function in HC.**
Methods: **We performed real-time 3D echocardiography on 26 patients with HC and on 15 control subjects. LA and LV time-volume curves were obtained from real-time 3D echocardiography and the maximal slope of the time-volume curve was expressed as dV/dt. LA active emptying fraction was calculated as: [(precontraction LA volume − minimal LA volume)/precontraction LA volume] × 100.**
Results: **The maximal LA volume index was larger, and LA active emptying fraction was lower, in those with HC than control subjects (50.1 ± 15.9 vs 30.1 ± 6.8 mL/m^2 and 33.3 ± 13.7 vs 40.4 ± 8.6%, both $P < .05$). LA active emptying fraction showed a negative correlation with precontraction LA volume ($r = -0.64$, $P < .01$) in HC. Patients with HC showed decreased LV early diastolic dV/dt compared with control subjects (0.10 ± 0.05 vs 0.14 ± 0.04 mL/ms, $P < .05$). LA passive and active emptying dV/dt were correlated with LV early and late diastolic dV/dt, respectively ($r = 0.47$ and $r = 0.48$, both $P < .05$).**
Conclusion: **Our 3D echocardiographic study showed that increased LA volume was related to decreased LA contraction in HC. LA passive emptying was related to LV relaxation whereas LA active contraction was related to LV stiffness.** (J Am Soc Echocardiogr 2006; 19:796-801.)

Left atrium (LA) in patients with hypertrophic cardiomyopathy (HC) has been known to have an increased size and decreased contractile function.[1] Enlarged LA size has a prognostic importance because it is related with the risk for supraventricular arrhythmia including atrial fibrillation in patients with HC.[2] In addition, LA dilation is associated with an increase in LA work and LA dysfunction.[1,3] LA dilation in patients with HC is related to LA afterload such as left ventricle (LV) filling pressure, LV outflow tract pressure gradient, LV wall thickness,[4] and LV diastolic dysfunction.[3] LA pressure and volume immediately before LA contraction are increased in patients with HC. Investigation of LA afterload revealed that the LV chamber stiffness constant was higher in patients with HC.[1]

HC is known to have abnormal LV filling during early diastole, manifested by diminished rate of rapid diastolic filling.[5] Although LV hypertrophy is considered to be an important determinant of diastolic dysfunction of LV, the relationship between LA contraction and LV relaxation has not been quantitatively investigated in HC.

The purpose of this study was to determine absolute LA and LV volume change and function using real-time 3-dimensional (3D) echocardiography (RT3DE) and to investigate association between LA contraction and LV relaxation, noninvasively.

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METHODS

Our institutional review board approved the protocol. We performed 2-dimensional and 3D echocardiography sequentially in the same day on 30 patients with HC and in sinus rhythm and 15 healthy control subjects. The diag-

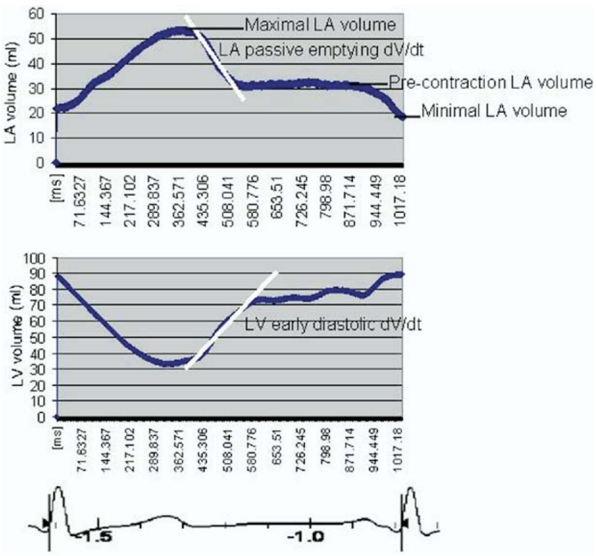

Figure 1 Schema of left atrial (*LA*) and left ventricular (*LV*) time-volume curve derived from real-time 3-dimensional echocardiography. LA passive emptying dV/dt and LV early diastolic dV/dt were determined as maximal slopes of time-volume curve of respective phases. LA active emptying fraction was determined as: [(precontraction LA volume − minimal LA volume)/(maximal LA volume − minimal LA volume)] × 100.

nosis of HC was based on echocardiographic demonstration of a hypertrophied, nondilated LV in the absence of other acquired or congenital heart disease.[6] Among 30 patients with HC, 4 patients were excluded because of moderate to severe mitral regurgitation.

Transthoracic 2-dimensional and pulsed Doppler echocardiography were performed. LV outflow tract obstruction at rest (pressure gradient > 30 mm Hg) was observed in 11 patients. In 9 patients without resting obstruction, pressure gradient of LV outflow tract more than 30 mm Hg developed during provocation with amyl nitrate inhalation. The LA image for quantitative analysis and Doppler study of transmitral blood flow and pulmonary vein flow were acquired in apical 4-chamber view. Each echocardiographic examination was stored digitally and reviewed offline with software (Prosolv Cardiovascular Analyzer, Problem Solving Concepts, Indianapolis, Indiana). The atrial filling fraction was also determined as the velocity time integral of late diastolic transmitral flow divided by that of total diastolic transmitral flow.

After 2-dimensional echocardiography, RT3DE was performed in apical views using a 2- to 4-MHz ×4 matrix-array transducer connected to an ultrasound system (Sonos 7500, Phillips, Andover, Mass). Three-dimensional LA and LV images were taken by wide-angled acquisition (full-volume method) during end expiration. Offline software (4D LV Cardio-view, TomTec, Munich, Germany) was used for displaying and quantifying the 3D images. We used modified automatic contour detection method in 7 cutting planes at each frame during one cardiac cycle for evaluating 3D volume data of the LA and LV. Time-volume curves of LA and LV were obtained with software (TomTec) by calculation of LA and LV volume. The maximal slope of the time-volume curve was expressed as dV/dt (Figure 1).

Table 1 Clinical characteristics

	Normal (n = 15)	HC (n = 26)
Age, y	36 ± 10	53 ± 16*
M/F	12/3	18/8
Height, cm	170.6 ± 8.0	176.2 ± 8.8*
Weight, Kg	76.3 ± 23.6	93.5 ± 23.7*
BSA, m^2	1.88 ± 0.30	2.12 ± 0.29*
Heart rate/min	63.8 ± 6.8	59.2 ± 10.3
HC, obstructive type		n = 20
LVOT PG, mm Hg		39.2 ± 40.0

BSA, Body surface area; *F*, female; *HC*, hypertrophic cardiomyopathy; *LVOT PG*, left ventricular outflow tract pressure gradient; *M*, male.
**P* < .05.

Early diastolic phase was determined from end-systolic LV volume to diastasis and late diastolic phase was determined from diastasis to end-diastolic LV volume. Early and late diastolic LV filling volumes were determined as the volume percentage of total LV filling volume in early and late LV diastolic phase. LV peak filling rate and time from end-systolic LV volume to peak filling rate in early diastolic phase were derived from time derivative of the time-volume curve of LV.

LA active emptying fraction (ActEF) was determined as the percent change between precontraction LA volume during ventricular diastolic phase and minimal LA volume after LA contraction derived from a time-volume curve by 3D echocardiography and calculated as: [(precontraction LA volume − minimal LA volume)/precontraction LA volume] × 100 (Figure 1). Active emptying percentage of total emptying was calculated as [(precontraction LA volume − minimal LA volume)/(maximal LA volume − minimal LA volume)] × 100. The LA expansion index was calculated as [(maximal LA volume − minimal LA volume)/minimal LA volume] × 100.

Interobserver and Intraobserver Variation

To assess interobserver and intraobserver variation in measuring LA volume, two independent investigators analyzed 10 echocardiograms and one investigator analyzed them twice. Interobserver variability for each parameter was calculated as the difference between the two measurements divided by the average of the two, and expressed in percent ± SD (%).

Statistical Analysis

Data are presented as mean ± SD. Statistical analyses were carried out with software (SPSS 10.0, McGraw-Hill, New York, NY). Values for HC and control groups were compared with an unpaired *t* test. To examine the correlation between LA and LV dV/dt and between 3D and Doppler data, Pearson regression analyses were used. A *P* value less than .05 was considered statistically significant.