

Left Atrial Volume Measured by Real-Time 3-Dimensional Echocardiography Predicts Clinical Outcomes in Patients with Severe Left Ventricular Dysfunction and in Sinus Rhythm

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Background: The clinical value of real-time 3-dimensional echocardiography assessments of left atrial volume in patients with left ventricular dysfunction has not been determined.

Methods: Real-time 3-dimensional echocardiography and 2-dimensional Doppler echocardiography were performed on the same day in 108 patients with severe left ventricular dysfunction and in sinus rhythm. End-systolic left atrial volumes were measured using real-time 3-dimensional echocardiography images (LAV-3D) and end-systolic left atrial volumes were calculated by the biplane area-length formula using 2-dimensional echocardiography (LAV-2D). Patients were observed clinically over 10 ± 7 months.

Results: LAV-2D showed excellent correlation with LAV-3D ($r = 0.88$, $P < .001$), but the former was significantly smaller than the latter (-12 ± 21 mL, $P < .001$). During follow-up, 31 patients (29%) showed clinical events, including 3 cardiac deaths and 28 hospitalizations as a result of heart failure. Patients with clinical events had larger initial LAV-3D ($P < .05$) and LAV-2D ($P = .05$), higher transmitral E velocity, higher E/E' ratio, more severe mitral and tricuspid regurgitation, and higher maximal velocity of tricuspid regurgitation than the 77 patients without events. LAV-3D ($P < .001$) and age ($P < .05$) were independent predictors of cardiac events by Cox proportional hazard model, whereas LAV-2D was negatively involved. Patients with initial LAV-3D less than 100 mL had a significantly higher 1-year event-free survival than those with LAV-3D greater than or equal to 100 mL (80 ± 7 vs $48 \pm 10\%$, $P < .001$).

Conclusions: LAV-3D is a major predictor of clinical events in patients with severe left ventricular dysfunction and in sinus rhythm. The clinical value of LAV-3D seems to be superior to that of LAV-2D.

Left atrial (LA) size, as assessed by LA volume measurement, is a marker of left ventricular (LV) diastolic dysfunction,¹⁻³ a predictor of new development of heart failure,^{4,5} and a major predictor of survival in patients with various cardiovascular diseases.⁶⁻¹³ Although 2-dimensional (2D) echocardiography (2DE) has been used to assess LA volume, this method involves assumptions regarding the LA shape and mathematic calculations, which may introduce significant discrepancies between LA volume measured by 2DE (LAV-2D) and true 3-dimensional (3D) LA volume. LA 3D features may differ from mathematically calculated ellipsoidal shapes and be subject to individual variations. Furthermore, 2DE images are dependent on the imaging plane and each patient's chest window¹⁴; LAV-2D may,

therefore, underestimate the true LA volume if the 2D imaging plane does not cross the center of the LA.

Real-time 3D echocardiography (RT3DE) may provide a more accurate determination of LA volume, because this method does not require any geometric assumptions.¹⁵⁻¹⁸ However, the clinical value of RT3DE measurements of LA volume (LAV-3D) has not been demonstrated. We, therefore, aimed to evaluate the prognostic value of LAV-3D compared with that of LAV-2D in patients with severe LV dysfunction and in sinus rhythm.

METHODS

Patient Population

A total of 116 consecutive patients with severe LV dysfunction (ejection fraction $\leq 35\%$) and in sinus rhythm were prospectively enrolled. Patients with organic mitral valvular disease, atrial fibrillation or frequent premature beats, and acute myocardial infarction within 2 months were excluded. Among the 116 patients enrolled, 8 were excluded as a result of dyspnea precluding breath hold for image acquisition and/or a very poor image quality for accurate RT3DE volume analysis. Consequently, 108 patients (age 61 ± 12 years, 37 female) were included in this study. The causes of LV dysfunction

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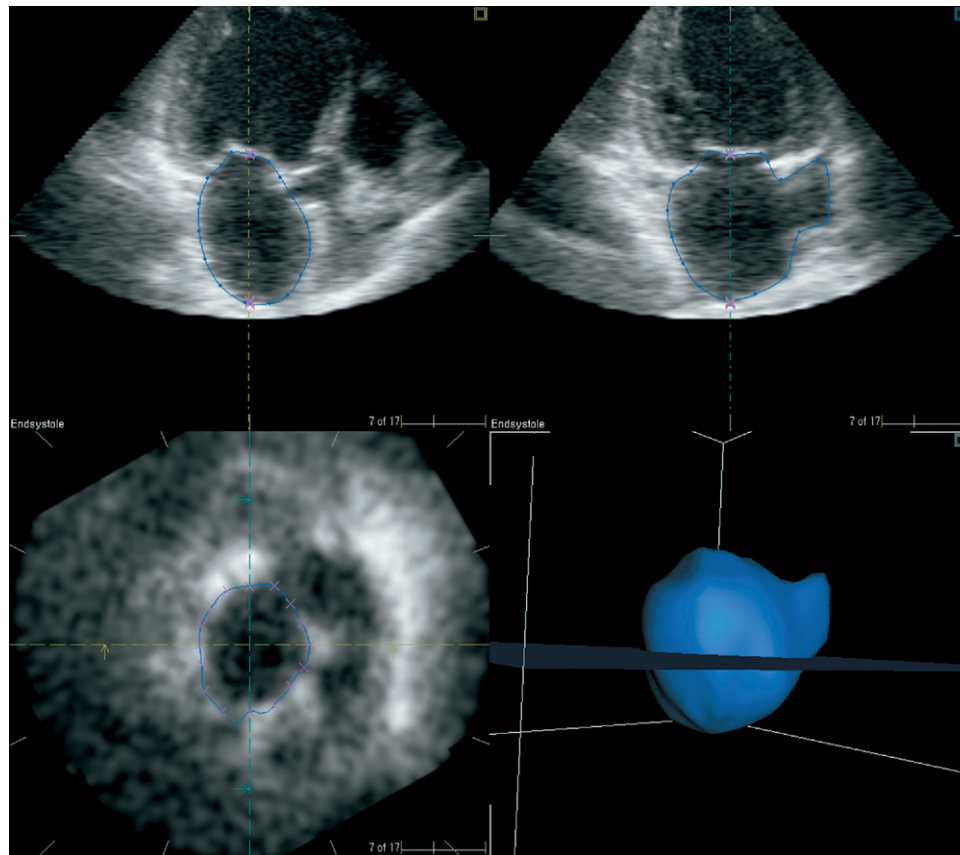


Figure 1 Representative example of left atrial (LA) volume measurement using real-time 3-dimensional echocardiography. Volume was measured at ventricular end systole just before opening of mitral valve by tracing LA areas in 8 radial planes 22.5 degrees apart from one another. Color figure online.

were dilated cardiomyopathy in 59 patients and ischemic cardiomyopathy in 49 patients.

RT3DE

A RT3DE system (Sonos 7500, Philips Medical Systems, Andover, MA) with a 2- to 4-MHz 3000-element xMATRIX transthoracic transducer was used to acquire full-volume 3D images. The images were obtained from the apical views with gain, compression controls, and time gain compensation settings optimized for image quality. Care was taken to include the entire LV and LA in the full-volume data set, and each data set was acquired in the wide-angled acquisition ($93^\circ \times 80^\circ$ -degree) mode, in which 4 wedge-shaped subvolumes ($93^\circ \times 20^\circ$ degrees each) were obtained from 4 different cardiac cycles during held respiration. Acquisition was triggered to the R wave of every other cardiac cycle to allow time for storage of each subvolume, resulting in a total acquisition time of 8 heartbeats. All images were stored digitally and analyzed offline.

Dedicated RT3DE software (Tomtec, Munich, Germany) was used for measurement of LAV-3D and LV volumes. LAV-3D was measured at ventricular end systole just before opening of the mitral valve by tracing LA areas in 8 radial planes 22.5 degrees apart from one another (Figure 1). LA appendage was included and pulmonary veins were excluded from the tracing. LV end-diastolic and end-systolic volumes were also measured, and ejection fraction was calculated. LA longitudinal (mitral annulus to superior wall), medial-lateral, and antero-posterior dimensions were also measured on RT3DE images at ventricular end systole.

2DE

For each patient, 2DE was performed on the same day as RT3DE, with 2DE images obtained in the standard parasternal and apical views, including the LA, with a transthoracic 3-MHz phased-array transducer (Sonos 7500, Philips Medical Systems). The LA antero-posterior dimension was measured by M-mode tracing from the parasternal view. LAV-2D was calculated using the biplane area-length formula, $8(A_1)(A_2)/3\pi(L)$, where A_1 and A_2 represent the maximal planimetered LA area acquired from the apical 4- and 2-chamber views, respectively, and L is length.¹⁹ LAV-2D was measured at ventricular end systole, and LA appendage and pulmonary veins were excluded from the area tracing.

Transmitral inflow profile and mitral annular velocity were traced to measure E and A wave velocities, deceleration time, and E' and A' velocities.²⁰ Mitral and tricuspid regurgitations were semiquantitatively assessed using color Doppler 2DE, with no regurgitation scored as 0, mild regurgitation as 1, mild to moderate regurgitation as 2, moderate regurgitation as 3, moderate to severe regurgitation as 4, and severe regurgitation as 5.⁷

Clinical Follow-up

Patients were observed clinically for 10 ± 7 months. Clinical data were obtained during patient visits to the hospital or by telephone interview and comprehensive review of medical records by a trained cardiologist. Clinical events were defined as cardiovascular death and hospitalization as a result of heart failure symptoms.

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