ATRIAL FILLING FRACTION OBTAINED BY AORTIC ROOT ECHOCARDIOMGRAM IN MAN

TAKAKO NAWATA, M.D., MASUNORI MATSUZAKI, M.D., YOSHITO ANNO, M.D.
YOICHI TOMA, M.D., TOSHIKICHI MAEDA, M.D., HIROSHI OGAWA, M.D.
YASUO MATSUDA, M.D., TOSHIKICHI KUMADA, M.D.
AND REIZO KUSUKAWA, M.D.

Atrial filling fraction obtained by left ventricular echocardiogram (AFF by LV echo) is considered to be a reliable measure of AFF of LV. However, in patients with LV asynergy, AFF by LV echo cannot be evaluated correctly by this method.

To obtain AFF, we devised a new echocardiographic index of AFF, obtained from the aortic-left atrial echogram (AFF by Ao echo), and examined the significance of this index in 9 normal subjects (Normals) and 49 patients with various heart diseases.

The correlation between AFF by Ao echo and left ventricular end-diastolic pressure (LVEDP) also was examined.

In an additional 20 patients with acute myocardial infarction (acute MI), the relationship between AFF by Ao echo and pulmonary arterial end-diastolic pressure (PAEDP) was studied for several days following the onset of MI.

Results were as follows: 1) In Normal patients and patients without asynergy, a significant correlation was seen between AFF by LV echo and AFF by Ao echo (r = 0.710, p < 0.001). The value of AFF by Ao echo was always greater than that by LV echo. 2) AFF by Ao echo in patients with hypertensive heart disease (HHD), angina pectoris (AP) and old myocardial infarction (old MI) was significantly higher than that in Normal patients. 3) A significant curvilinear correlation was seen between AFF by Ao echo and LVEDP (r = 0.673, p < 0.005). 4) In patients with acute MI, AFF by Ao echo correlated well with PAEDP.

Therefore, AFF by Ao echo, a newly devised parameter, may be a useful, convenient and non-invasive index for estimating actual AFF and for evaluating the day to day changes of LV end-diastolic performance in acute MI.

BGLOSSARY

pump action of the left atrium is very important for left ventricular filling in patients with decreased left ventricular compliance such as left ventricular hypertrophy or myocardial infarction. Atrial contribution to left ventricular stroke volume, that is, atrial filling fraction (AFF), has been studied by many investigators.

Echocardiography has been a useful tool in the evaluation of left ventricular function and some investigators have measured atrial filling fraction using left ventricular echogram (AFF by LV echo) in patients with various heart

Key Words:
Atrial filling fraction
Aortic root echocardiogram
Left ventricular filling pressure
Left ventricular asynergy

(Received March 22, 1985; accepted January 9, 1986)
The Second Department of Internal Medicine, Yamaguchi University School of Medicine, Ube, Japan
Mailing address: Takako Nawata, M.D., Division of Internal Medicine, Onoda City Hospital, 1863-1, Higashi Takatomari, Onoda-city, Yamaguchi 756, Japan

Fig.1. Echocardiographic determination of AFF obtained by echograms of left ventricle (upper panel: A) and aortic root (lower panel: B) in a normal, 56-year-old man. 
Dd = left ventricular end-diastolic dimension; Ds = left ventricular end-systolic dimension; Da = left ventricular dimension at the beginning of atrial contraction; 
DdV = left ventricular end-diastolic volume using Teichholtz’s method; DsV = left ventricular end-systolic volume using Teichholtz’s method; DaV = left 
ventricular volume at the beginning of atrial contraction using Teichholtz’s 
method; E1 = the maximum posterior wall excursion of the aorta; E2 = the 
posterior wall excursion of the aorta during atrial contraction; L1 = the maximum 
left atrial dimension; L2 = left atrial dimension at the beginning of atrial contrac-
tion

In this study, we devised a new echocardiographic index of left ventricular AFF obtained 
by the aortic-left atrial echogram (AFF by Ao echo), which is free from the influence of left 
ventricular asynergy, and examined the clinical significance of this index. The relationships 
among this index, AFF by LV echo and left ventricular end-diastolic pressure (LVEDP) were 
studied in patients with various heart diseases. In patients with acute myocardial infarction, the 
relationship between this index and pulmonary arterial end-diastolic pressure (PAEDP) was 
studied for several days following the onset of myocardial infarction.

MATERIALS AND METHODS

Echocardiograms from 9 normal subjects (Normal: male (M): 5, female (F): 4, 44 to 59 
years, mean: 51) and 69 patients with various heart diseases were examined. The latter included 
9 patients with hypertensive heart disease (HHD: M: 7, F: 2, 49 to 67 years, mean: 57), 
17 with angina pectoris (AP: M: 17, 51 to 71
TABLE I ATRIAL FILLING FRACTIONS OBTAINED BY TWO METHODS AND OTHER MEASUREMENTS IN NORMAL PATIENTS AND PATIENTS WITH VARIOUS HEART DISEASES (n = 58) (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Age (years)</th>
<th>AFF by LV echo (%)</th>
<th>AFF by Ao echo (%)</th>
<th>LVEDP (mmHg)</th>
<th>L₁-index (mm/M²)</th>
<th>L₂-index (mm/M²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>9</td>
<td>51.3 ± 5.0</td>
<td>22.3 ± 2.8</td>
<td>39.6 ± 4.4</td>
<td>9.7 ± 2.4</td>
<td>23.9 ± 3.1</td>
<td>21.0 ± 2.9</td>
</tr>
<tr>
<td>HHD</td>
<td>9</td>
<td>57.2 ± 6.3</td>
<td>31.2 ± 4.5*</td>
<td>48.0 ± 5.6*</td>
<td>9.1 ± 2.6</td>
<td>23.4 ± 2.9</td>
<td>21.1 ± 3.3</td>
</tr>
<tr>
<td>AP</td>
<td>17</td>
<td>59.1 ± 6.8*</td>
<td>29.9 ± 5.5*</td>
<td>45.9 ± 4.1*</td>
<td>8.6 ± 2.7</td>
<td>21.4 ± 3.4</td>
<td>18.7 ± 3.4</td>
</tr>
<tr>
<td>old MI</td>
<td>23</td>
<td>55.3 ± 6.4</td>
<td>—</td>
<td>50.1 ± 6.5*</td>
<td>13.7 ± 6.2</td>
<td>23.1 ± 3.1</td>
<td>20.9 ± 3.3</td>
</tr>
</tbody>
</table>

*p < 0.01, compared with normal subjects
M = male; F = female; HHD = hypertensive heart disease; AP = angina pectoris; MI = myocardial infarction; L₁ = the maximum left atrial dimension; L₂ = left atrial dimension at the beginning of atrial contraction

years, mean : 59), 23 with old myocardial infarction (old MI: M : 21, F : 2, 46 to 67 years, mean : 55) and 20 with acute myocardial infarction (acute MI: M : 14, F : 6, 40 to 75 years, mean : 58). All patients had sinus rhythm and had heart rates ranging from 50 to 100 beats per minute.

In all of the Normal patients and all patients except those in the acute MI group, right and left heart catheterization and selective coronary arteriography were performed and LVEDP was determined before ventriculography. Left heart pressure was measured by Millar Micro-Tip catheter. In all 20 patients with acute MI, right heart catheterization using Swan-Ganz catheter was performed immediately after admission to the coronary care unit, and the pulmonary arterial pressure and echocagrams were obtained at the same time during several consecutive days.

Echocardiograms were obtained using Toshiba SSH-11A or Alok SSD-110S simultaneously with electrocardiogram (lead II) and phonocardiogram at a paper speed of 50 or 100 mm/sec within one week of catheterization. Left ventricular and aortic root echograms were recorded in supine or left decubitus position with the transducer placed in the third or fourth intercostal space at the left sternal border.

A representative example of left ventricular (upper panel: A) and aortic-left atrial echograms (lower panel: B) in a Normal subject is shown in Fig. 1. From the left ventricular echogram, left ventricular end-diastolic (Dd) and end-systolic dimensions (Ds), and the left ventricular dimension at the beginning of atrial contraction (Da) were measured. Left ventricular end-diastolic (DdV) and end-systolic volumes (DsV), and the left ventricular volume at the beginning of atrial contraction (DaV) were calculated by Teichholtz's formula. Then, atrial filling fraction (AFF) was determined by the formula [DdV-DaV / DdV-DsV] x 100 (AFF by LV echo (%)). From the aortic-left atrial echogram, the maximum posterior wall excursion of the aorta (E₁), the posterior wall excursion of aorta during atrial contraction (E₂), the maximum left atrial dimension (L₁) and the left atrial dimension at the beginning of atrial contraction (L₂) were measured. L₁ and L₂ were shown as a normalized value

Japanese Circulation Journal Vol. 50, March 1986
Fig. 3. AFF obtained by both methods in 9 normal subjects and 49 patients with various heart diseases.

Fig. 4. Relationship between AFF by Ao echo and left ventricular end-diastolic pressure in normal subjects and patients with various heart diseases.

by body surface area (L₁, L₂-index). We have previously reported that the product of the posterior aortic wall excursion and maximum left atrial dimension (E₁ × L₁) was highly correlated with mitral flow volume. On the basis of this concept, the product of the posterior wall excursion of the aorta during atrial contraction and the left atrial dimension at the beginning of atrial contraction (E₂ × L₂) were considered atrial contributions for total mitral flow volume. Thus, a new echocardiographic index of AFF obtained from the aortic-left atrial echo, AFF by Ao echo (%), was determined by the formula \[ \frac{E₂ \times L₂}{E₁ \times L₁} \times 100. \] In the case shown in Fig. 1, for example, AFF by LV echo was 24% and AFF by Ao echo was 40%.

Statistical analyses were made using unpaired T-tests and the data were expressed as a
AFF by Aortic Root Echo in Man

ACUTE MI (20P)

ANTERO-SEPTAL MI

infero-posterior MI

CHRONIC STATE

y = 1.76 - 0.009x + 0.0037x^2

r = 0.694
p < 0.005
F = 32.6
N = 73

Fig.5. Relationship between AFF values by Ao echo and those of pulmonary arterial end-diastolic pressure in 20 patients with acute myocardial infarction.

mean ± SD.

RESULTS

Data of AFF by LV echo, AFF by Ao echo, left atrial dimensions and LVEDP in patients in this study are summarized in Table I.

There was a good correlation between AFF by LV echo and AFF by Ao echo for all 35 patients without left ventricular asynery (r = 0.710, p < 0.001) (Fig. 2). The values of AFF by Ao echo were estimated higher than those by LV echo (y = 25.69 ± 0.68x).

AFF by LV echo was 22.3 ± 2.8% in Normal patients, 31.2 ± 4.5% in HHD, and 29.9 ± 5.5% in AP (left panel in Fig. 3). AFF by Ao echo was 39.6 ± 4.4% in Normal patients, 48.0 ± 5.6% in HHD, 45.9 ± 4.1% in AP and 50.1 ± 6.5% in old MI (Fig. 3, right panel). AFF values in patients with heart diseases evaluated in this study were significantly higher than those in Normal patients. AFF values in patients with old MI were highest.

The relationship between LVEDP and AFF by Ao echo was examined. A significant curvilinear correlation was seen between these two parameters (r = 0.673, p < 0.005), and the increment of AFF followed the elevated LVEDP in patients with various heart diseases (Fig. 4).

We examined the correlation of L2-index with AFF by Ao echo. There was a statistically significant correlation between these two parameters (r = 0.376, p < 0.01), and as the parameter of L2-index increased, AFF increased correspondingly.

In 20 patients with acute MI, the relationship between AFF by Ao echo and PAEDP was studied for several consecutive days following the onset of MI (Fig. 5). Day to day changes of AFF correlated well with those of PAEDP, and the relationship of these parameters fitted on a curvilinear graph (r = 0.694, p < 0.005). However, in patients with acute myocardial infarction, daily values of AFF by Ao echo were not significantly different over a few days after the onset of myocardial infarction.

In all 20 patients with acute MI, there was a significant correlation between daily values of AFF by Ao echo and L2-indice following the onset of acute MI, and as the parameter of the L2-index increased, AFF increased correspondingly (r = 0.578, p < 0.001).

DISCUSSION

Since Harvey first suggested the importance of atrial contribution to cardiac function in 1628,

Japanese Circulation Journal  Vol. 30, March 1986
there have been many reports about booster pump action of the left atrium. Wiggers and Katz showed that the volume of blood contributed by atrial systole was 18 to 60% (average 35%) of the total volume of blood that entered the ventricles during diastole under normal conditions. According to Rahimtoola et al., the average of AFF was 21.7% in the control group and 35.1% in myocardial infarction. Other investigators reported that AFF in patients with left ventricular hypertrophy or ischemic heart disease was significantly higher than that in the control group. We performed this study to obtain AFF using M-mode echocardiography in patients with and without left ventricular asynergy, and to evaluate the day to day changes of left ventricular late diastolic performance in acute MI. The following three echocardiographic measurements have been reported to estimate mitral flow volume: 1) Left ventricular echogram has been used primarily in the conventional manner. However, using LV echogram for estimating mitral flow volume in patients with left ventricular asynergy has frequently led to misleading results. 2) Mitral valve echogram; this method is free from the influence of left ventricular asynergy. 3) Aortic root echrogram; it has been suggested that this method was useful for estimating mitral flow volume in patients with and without left ventricular asynergy. It is naturally assumed that these three methods can be applied for estimating AFF.

In this study, we used the product of excursion and dimension of the left atrium as an index of left atrial volume change. Except for markedly dilated left atrium, left atrial configuration is considered to be an ellipsoid. Therefore, both long and short axis dimensions of LA are necessary for obtaining actual LA volume. However, it is sometimes difficult to observe the long axis view of the left atrium by echocardiography. We used our index (excursion × dimension) as an index for evaluating LA volume. The values of AFF by Ao echo were always higher than those of AFF by LV echo in patients without LV asynergy (17% in Normal, 17% in HHD and 16% in AP), indicating AFF by Ao echo might overestimate the actual AFF. During mid-diastolic period, LA acts as a conduit from the pulmonary vein into the left ventricle. Usually the left atrial dimension is not significantly changed in this period (LV slow filling phase). We thought that an index of total mitral flow which was calculated by multiplying the total LA excision in a cardiac cycle by maximum LA dimension (E1 × L1) might underestimate AFF, because of disregard of the direct flow from the pulmonary vein into the left ventricle during LV slow filling period, when LA dimension was relatively constant. We could speculate that this underestimation of the index of total mitral flow (E1 × L1) was one of the reasons why the values of AFF by Ao echo were always greater than those of AFF by LV echo. However, there was a significant correlation between AFF by Ao echo and AFF by LV echo in patients without LV asynergy.

AFF values in patients with various heart diseases evaluated in this study were significantly higher than those in normal patients. Since AFF in patients with old MI was highest, it was considered important that atrial fibrillation be prevented in patients with old MI.

Atrial contraction not only increases left ventricular end-diastolic volume as stated before, but also elevates LVEDP. Many investigators have reported the relationship between AFF and LVEDP. Therefore, we examined the correlation of AFF by Ao echo with LVEDP. Significant curvilinear correlation was seen and the increment of AFF corresponded closely to the elevation of LVEDP.

In 1961, Braunwald reported Starling’s law of left atrium. In this study, a statistically significant correlation was seen between the index of the left atrial dimension at the beginning of the atrial contraction and AFF. This finding supports the concept that Starling’s law is operative in the human left atrium.

Nieminen et al. reported that both overall and regional myocardial performance were worst within the first 3 days of infarction, improving thereafter in surviving patients. It was also reported that compliance of the infarcted left ventricle increased several hours after the onset of infarction and decreased later in the course of MI. In our study, no significant changes were noted in AFF by Ao echo for several days following the onset of MI. These results were ascribed to the drugs used for therapy, i.e., nitroprusside nitroglycerine, dopamine, digitalis, Ca-antagonist, diuretics, low molecular weight dextran, etc., during acute phase of myocardial infarction.

However, it should be a useful and noninvasive index for estimating the relative changes of left atrial filling fraction, and for evaluating the day to day changes of left ventricular late dia-
stolic performance in acute myocardial infarction.

REFERENCES


4. WIGGERS CJ, KATS LN: The contours of ventricular volume curves under different conditions. Amer J Physiol 58: 439, 1922


7. STOTT DK, MARPOLE DGF, BRISTOW JD, KLOSTROD FE, GRISWELL HE: The role of left atrial transport in aortic and mitral stenosis. Circulation 41: 1031, 1970


17. TEICHHOULTZ LE, KLEULEN T, HERMAN MV, GORLIN R: Problems in echocardiographic-angiographic correlations in the presence or absence of asynergy. Amer J Cardiol 37: 7, 1976


20. TYE K, DESSER KB, BENCHIMOL A: Relation between apexcardiographic A wave and posterior aortic wall motion. Amer J Cardiol 43: 24, 1979


Japanese Circulation Journal Vol. 50, March 1986