Clinical Significance of Fibrillatory Wave Amplitude:
A Clue to Left Atrial Appendage Function in Nonrheumatic Atrial Fibrillation

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Seventy-eight patients with chronic nonrheumatic atrial fibrillation were studied by transesophageal echocardiography with regard to the left atrial appendage function and its relation to the coarseness of atrial fibrillation on electrocardiogram. These 78 patients (52 men and 26 women; mean age, 66±10 years; range, 40 to 94 years) were classified into two groups according to the presence of coarse (group 1, n=46; those with the greatest amplitude of fibrillatory wave in lead V1≥1 mm) or fine (group 2, n=32; those without the coarse fibrillatory wave in lead V1) atrial fibrillation on a standard 12-lead electrocardiogram within 1 month of echocardiographic studies. There were no significant differences in age, sex, mean duration of atrial fibrillation, left ventricular end-diastolic dimension, left ventricular end-systolic dimension, left ventricular ejection fraction, and left atrial dimension between the two groups. In group 1, however, the left atrial appendage ejection fraction (24.4±14.2% vs 32.6±14.8%; p<0.05) and the peak emptying velocity (21.7±12.6 cm/s vs 30.4±14.3 cm/s; p<0.01) were lower than those in group 2. There were higher incidences of left atrial appendage spontaneous echo contrast (26/46 vs 7/32; p<0.005) and thrombus (8/46 vs 0/32; p<0.05) in group 1 patients. The coarse atrial fibrillation revealed a sensitivity of 80.0%, a specificity of 58.1%, a positive predictive value of 60.9%, and a negative predictive value of 78.1% for the presence of left atrial appendage spontaneous echo contrast and/or thrombus formation. In conclusion, in patients with coarse nonrheumatic atrial fibrillation, the left atrial appendage function is usually poor and the incidence of spontaneous echo contrast and thrombus formation appears to be higher in these patients.

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AF=atrial fibrillation; LA=left atrium

**Key words:** atrial fibrillation; electrocardiogram; left atrial appendage

The amplitude of atrial fibrillatory wave on the electrocardiogram varies from coarse to flat-line. Previous studies\(^1\)\(^-\)\(^3\) have suggested that higher fibrillatory wave amplitude is associated with larger left atrial (LA) size. In patients with rheumatic mitral valve disease, Daniel et al\(^4\) found that the LA size was larger in the presence of LA spontaneous echo contrast or thrombi. Black et al\(^5\) also reported that the LA dimension was increased in patients with nonrheumatic atrial fibrillation (AF) associated with LA spontaneous echo contrast. Since the LA appendage is the predilection site for both spontaneous echo contrast and thrombus formation,\(^6\)\(^,\)\(^7\) its contractile function has received much attention recently.\(^8\)\(^-\)\(^10\) It was reported by Garcia-Fernandez et al\(^10\) that poor LA appendage function was associated with larger LA and LA appendage size as well as higher incidence of spontaneous echo contrast or thrombus formation. The purpose of this study was to find the possible relationship between the coarseness of fibrillatory wave in patients with nonrheumatic AF and the LA appendage function, LA appendage spontaneous echo contrast, or thrombus formation.

**M**

**Methods**

**Patients**

From June 1992 through March 1994, 78 patients diagnosed as having chronic nonrheumatic AF in outpatient clinics or medical wards at our institution were enrolled in this study. The chronic nonrheumatic AF was defined as AF that was documented by a 12-lead electrocardiogram and lasted for more than 6 months. There was no evidence of mitral stenosis or regurgitation of a rheumatic nature; patients with a mitral valve prosthesis or any previous cardiac surgery were also excluded. The duration of AF was estimated from the time of the first documented electrocardiogram to the time of echocardiographic study. In all, there were 52 men and 26 women, with a mean age of 66±10 years (range, 40 to 94 years). The etiology of AF included the following: hypertensive cardiovascular disease (n=23); atherosclerotic heart disease...
Echocardiography

All patients underwent transthoracic and transesophageal echocardiographic studies. The transthoracic echocardiography was performed with a 2.5- or 3.75-MHz phased-array transducer connected to an ultrasonic system (Aloka SSD-870; Aloka Corp Ltd; Tokyo, Japan). The M-mode measurements were determined according to the standards of the American Society of Echocardiography.11 The left ventricular ejection fraction was calculated from the method developed by Teichholz et al.12 Transesophageal echocardiography was performed according to the method described by Seward et al13 with a 5-MHz biplane transducer mounted at the tip of the gastroscope and connected to the same ultrasonic system (Aloka). All the patients were studied in the fasted state without any premedications except topical anesthesia of the hypopharynx with lidocaine spray. The LA appendage was visualized clearly in 73 patients from the basal short-axis view in the transverse scan. In the remaining five patients, the LA appendage was observed from the left atrium-left ventricle two-chamber view in the longitudinal scan due to the poor image quality in the transverse scan. First of all, the LA appendage area was measured with the method used by Pollick and Taylor14 and us.15 In brief, the area was estimated with planimetry by tracing a line from the limbus of the left upper pulmonary vein to the aorta at its shortest distance and along the whole LA appendage endocardial border. The maximal and minimal appendage areas were determined independently of the electrocardiogram. Two observers who were blind to each other determined the maximal and minimal appendage areas in 20 randomly selected subjects. The interobserver variability was calculated and the correlation of the measurements of the left atrial appendage maximal and minimal areas between the two observers was good (r=0.886 and 0.867, respectively). The LA appendage ejection fraction was calculated as (LA appendage maximal area-minimal area)/LA appendage maximal area×100%. Subsequently, we measured the LA appendage flow pattern and the peak emptying velocity by placing the sample volume into the LA appendage near its outlet. The Doppler flow patterns were classified into high- or low-flow profiles according to the method described by Muggge et al15 and us.16 In brief, a high-flow profile included the patients with multiphasic and well-defined LA appendage Doppler flow signals. The low-flow profile was defined as a very low Doppler flow velocity (<25 cm/s) and, sometimes, no flow signal at all could be detected. Two independent observers analyzed the Doppler flow pattern and any discrepancy in the determination was resolved by a third observer’s opinion. Finally, the presence of LA appendage thrombus or spontaneous echo contrast was assessed. The thrombus was diagnosed by the presence of an echogenic mass with a clearly defined contour that was distinct from the underlying endocardial surface. The influence of the pectinate muscles was carefully excluded. The spontaneous echo contrast was defined as dynamic smokelike echoes with a characteristic swirling motion. The influence of the white noise artifact was excluded by adjusting the gain setting as required. The presence or absence of thrombus or spontaneous echo contrast was determined by two independent observers and any difference in the determination was resolved by a third observer’s opinion.

Electrocardiogram

Standard 12-lead electrocardiograms of all patients were obtained within 1 month of the echocardiographic studies. All electrocardiograms were standardized to normal speed (25 mm/ min) and sensitivity that 1 mV input produced a 10-mm deflection. These electrocardiograms were classified into coarse or fine AF according to the method described by Peter et al.2 The fibrillatory wave with the greatest size was measured in lead V1. It was measured from the upper edge of the peak to the upper edge of the trough and was expressed in millimeters. Coarse AF was defined as any fibrillatory wave in lead V1 with an amplitude ≥1 mm, while those with all fibrillatory waves in V1 <1 mm were designated as fine AF. A single coarse fibrillatory wave in lead V1 was considered sufficient to classify the patient as having coarse AF. The influences of the artifact on the baseline and the T or U waves were carefully excluded. All classifications were performed by two independent observers. Eight of 78 (10.2%) electrocardiograms were classified with different opinions and the discrepancy was resolved by a third observer.

Statistical Analysis

All data were collected prospectively. The Student’s t test was used to compare the continuous variables. The χ2 test was used to compare the categoric variables. The association of LA appendage spontaneous echo contrast and/or thrombus with the presence of coarse AF was analyzed by calculating sensitivity, specificity, and positive and negative predictive values.

RESULTS

Patient Characteristics

All the patients were divided into two groups according to the presence of coarse (group 1, n=46) or fine AF (group 2, n=32) on the standard 12-lead electrocardiogram. The baseline patient characteristics and the routine transthoracic echocardiographic M-mode measurements were listed in Table 1. No significant difference was found in age, sex, duration of AF, left ventricular end-systolic dimension, left ventricular end-diastolic dimension, left ventricular ejection fraction, and LA dimension between the two groups. The use of antiplatelet or anticoagulant agents at the time of echocardiographic study also revealed no difference in these two groups.

Coarse AF and LA Appendage Function

Table 2 compared the LA appendage function including its size, contractility, peak emptying velocity, and the Doppler flow pattern between the two groups. Overall, the maximal and minimal appendage areas revealed no significant difference. The LA appendage ejection fraction, however, was significantly reduced in patients with coarse AF (group 1). More striking was the difference in LA appendage peak emptying velocity, which was also significantly reduced in group 1 patients (21.7±12.6 cm/s vs 30.4±14.3 cm/s; p<0.01). In view of the LA appendage blood flow pattern, 29 (63.0%) of 46 patients with coarse AF were found to have a low-flow profile in the Doppler studies, while only 9 (28.1%) of 32 patients with fine AF had a low-flow profile (p<0.005).

Association of Coarse AF With Spontaneous Echo Contrast and Thrombus Formation

Thirty-three (42.3%) of 78 patients were found to
have LA appendage spontaneous echo contrast (Table 2), all of which were detected by transesophageal echocardiography only. Patients with coarse AF were found to have a higher incidence of LA appendage spontaneous echo contrast than those with fine AF (26/46 vs 7/32; p<0.005). Eight (10.3%) of 78 patients had a LA thrombus that was all restricted to the appendage and detected by transesophageal echocardiography only. LA appendage spontaneous echo contrast was present concomitantly in six of these eight patients. All the eight patients had coarse AF. For the association of LA appendage spontaneous echo contrast and/or thrombus, coarse AF revealed a sensitivity of 80%, a specificity of 58.1%, a positive predictive value of 60.9%, and a negative predictive value of 78.1% in predicting the presence of blood stasis in the LA appendage.

**DISCUSSION**

**Coarse AF and LA Size**

Electrocardiographically, AF is characterized by disorganized atrial electrical activity and is classified into coarse or fine according to the fibrillatory wave amplitude. Various workers have studied the relation between the LA size and the fibrillatory wave amplitude. In an analysis of 194 patients with rheumatic or nonrheumatic AF, Thurmann and Janney\(^1\) found that coarse fibrillatory wave was associated with LA enlargement that was detected by roentgenologic studies. Peter et al\(^3\) reported that coarse fibrillatory waves in nonrheumatic AF corresponded to an abnormal lead V1 p-wave terminal force, an indicator of LA hypertrophy, after reverting to sinus rhythm. With the advent of a new diagnostic tool, Aysha and Hassan\(^17\) observed that the fibrillatory wave amplitude correlated strongly with the echocardiographic LA size. Bartall et al\(^8\) also reported that large fibrillatory waves were rarely observed on electrocardiogram with echocardiographically normal LA size. In addition to the LA size, coarse fibrillatory wave was also related to LA dysfunction. In a catheterization study group reported by Thurmann and Janney,\(^1\) coarse AF was found to be present in patients with elevated LA pressure. Skoulas and Horlick\(^10\) also found that coarse fibrillatory wave in patients with congestive heart failure could become fine after digitalization and relief of the heart failure. However, different results were reported from Morganroth et al.\(^20\) In an analysis of 37 patients with AF, the relationship between coarse fibrillatory wave and the echocardiographic size of LA could not be established. The different number of patients with rheumatic heart disease included for study may be the cause of the different result. In the current study, all patients with rheumatic heart disease were excluded and only those with nonrheumatic AF were included. Although there was no significant difference in the LA size between the patients with coarse or fine AF, the possible relation of coarse fibrillatory wave to LA dysfunction inspired us to work on the LA appendage function.

**Coarse AF and LA Appendage Function**

In the current study, there was no significant difference in the LA appendage size in patients with or without coarse AF. However, the LA appendage contractile function was markedly different. In patients with coarse AF, the LA appendage ejection fraction was decreased, and the peak emptying velocity was reduced. The LA appendage Doppler flow patterns were also different. In the results reported by Muge et al.,\(^15\) there existed two different LA appendage blood flow patterns: a high-flow profile with a less incidence of spontaneous echo contrast formation, and a low-flow profile with reduced LA appendage contractility and a higher incidence of spontaneous echoes. Most patients

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**Table 1—Baseline Patient Characteristics and Routine Transthoracic Echocardiography M-mode Measurements in the Two Patient Groups**

<table>
<thead>
<tr>
<th>Group 1 (n=46)</th>
<th>Group 2 (n=32)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, male/female</td>
<td>32/14</td>
<td>20/12</td>
</tr>
<tr>
<td>Age, yr</td>
<td>65.5±10.9</td>
<td>66.1±10.5</td>
</tr>
<tr>
<td>Duration of AF, mo</td>
<td>40.6</td>
<td>41.9</td>
</tr>
<tr>
<td>Current anticoagulant treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warfarin</td>
<td>1/46</td>
<td>0/32</td>
</tr>
<tr>
<td>Aspirin</td>
<td>11/46</td>
<td>8/32</td>
</tr>
<tr>
<td>LVEDD, mm</td>
<td>50.7±7.7</td>
<td>47.1±6.5</td>
</tr>
<tr>
<td>LVESD, mm</td>
<td>34.3±8.4</td>
<td>30.5±7.6</td>
</tr>
<tr>
<td>LVEF, mm</td>
<td>63.7±12.1</td>
<td>68.3±12.9</td>
</tr>
<tr>
<td>LAD, mm</td>
<td>40.5±6.2</td>
<td>39.4±7.9</td>
</tr>
</tbody>
</table>

* LVEDD=left ventricular end-diastolic dimension; LVESD=left ventricular end-systolic dimension; LVEF=left ventricular ejection fraction; LAD=left atrial dimension; NS=no significance.

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**Table 2—Left Atrial Appendage Size, Flow Velocities, Flow Patterns, and Blood Stasis in the Two Patient Groups**

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (n=46)</th>
<th>Group 2 (n=32)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal LAA area, cm²</td>
<td>6.0±2.6</td>
<td>6.3±1.7</td>
<td>NS</td>
</tr>
<tr>
<td>Minimal LAA area, cm²</td>
<td>4.4±2.0</td>
<td>4.4±1.6</td>
<td>NS</td>
</tr>
<tr>
<td>LAA ejection fraction, %</td>
<td>24.4±14.2</td>
<td>32.6±14.8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LAA emptying velocity, cm/s</td>
<td>21.7±12.6</td>
<td>30.4±14.3</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>LAA flow pattern (high flow profile/low flow profile)</td>
<td>17/29</td>
<td>23/9</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>LAA spontaneous echo contrast</td>
<td>26/46</td>
<td>7/12</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>LAA thrombus</td>
<td>8/46</td>
<td>0/32</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

*LAA=left atrial appendage; NS=no significance.*
with coarse AF were found to have a low-flow profile in LA appendage Doppler studies. These results indicate that coarse AF may be associated with LA appendage dysfunction. It is interesting to speculate on the underlying pathophysiologic mechanism between the coarse AF and the reduced LA appendage function. Previous studies21,22 have demonstrated that progressive atrial enlargement may occur as a consequence of AF even in patients without significant structural heart disease. The progressive enlargement of LA size may produce the coarseness of AF. Under the clinical course to LA enlargement, the increased wall stress and the decreased compliance may produce atrial contractile dysfunction. This may be more easily detected from the left atrial appendage by transesophageal echocardiography. In a preliminary study in patients with nonrheumatic AF reported by Blackshear et al.,23 the maximum fibrillatory wave amplitude in lead V1 is not associated with LA size, left ventricular mass, or left ventricular dysfunction. But the amplitude is smaller in paroxysmal AF than that in chronic AF which usually has worse LA appendage function. However, these speculations need to be confirmed by further studies.

**LA Spontaneous Echo Contrast and Thrombus Formation**

Patients with nonrheumatic AF were found to have a fivefold increased risk of thromboembolism,24 and the LA spontaneous echo contrast or thrombus had been proved to be the predictors for the increased embolic risk in such patients.25,26 However, detection of LA spontaneous echo contrast or thrombus largely depends on the semi-invasive procedure—transesophageal echocardiography. In the current study, coarse AF on surface electrocardiogram was found to have a relatively high sensitivity for detecting the presence of LA appendage spontaneous echo contrast and/or thrombus. The mechanism of this association might relate to the compromised LA appendage function. In nonrheumatic patients with AF who have contraindications or refuse the transesophageal echocardiographic examination, the 12-lead electrocardiogram may be used as a diagnostic tool for the identification of the LA appendage blood stasis.

**Study Limitation**

Clinically, it is not difficult to get an electrocardiogram and define it as a coarse or fine AF. However, the prevailing pattern of fibrillatory waves may change from one category to another. The cause of such change is multifactorial and the shortest interval of change is unknown. Further prospective longitudinal follow-up of patients with nonrheumatic AF using the electrocardiogram and transesophageal echocardiography may clarify such problems.

Currently, in our country, anticoagulation is not routinely prescribed to patients with nonrheumatic AF. Because the patient number receiving warfarin was small in this study, the effect of anticoagulant treatment on the LA appendage blood stasis could not be assessed. There were only ten patients with previous embolism history in the current series. Owing to the small patient number with embolism, the relation between the coarse AF and the occurrence of peripheral thromboembolism needs further study.

**REFERENCES**

19 Skoulas A, Horlick L. The atrial F wave in various types of heart disease and its response to treatment. Am J Cardiol 1964; 14:174-77