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Left Atrial Appendage Ejection Flow Waves in Differentiation of Atrial Flutter from Atrial Fibrillation

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ABSTRACT

Background: Atrial Flutter (AFL) and Atrial Fibrillation (AF) are among the most common supraventricular tachyarrhythmias. Sometimes, differentiation of the two arrhythmias using surface electrocardiography becomes difficult.
Objectives: This study aimed to compare the Left Atrial Appendage (LAA) ejection flow waves of AFL and AF to determine whether it can serve as a method for differentiating the two arrhythmias.
Methods: This cross-sectional study was conducted on 20 patients with AF and 20 ones with AFL selected via simple sampling method. During Trans-Esophageal Echocardiography (TEE), pulsed Doppler sampling was laid 1 cm inside the LAA and pattern of LAA ejection flow waves was recorded in terms of rate (number per minute), velocity (centimeter per second), and regularity. The two groups were compared using Mann-Whitney U-test. $P \leq 0.05$ was considered to be statistically significant.
Results: The rate of LAA ejection flow waves was 493.75 ± 50.57 in the AF group and 303.50 ± 16.31 in the AFL group ($P < 0.001$). Besides, the mean velocity was 0.172 ± 0.069 m/s in the AF group and 0.302 ± 0.106 m/s in the AFL group ($P < 0.001$). Velocity more than 0.17 m/s had a sensitivity of 95.0% (95% CI, 75.1 - 99.2%), specificity of 70.0% (95% CI, 45.7 - 88.0%), positive predictive value of 76.0%, and negative predictive value of 93.03% for diagnosing AFL. All patients in the AF group had irregular patterns, but all those in the AFL group had regular patterns.
Conclusion: Since TEE is a usual part for evaluation of patients suspected to have AF or AFL, it may be helpful for differentiating AFL from AF by examining LAA ejection flow waves.

1. Background

Atrial Flutter (AFL) and Atrial Fibrillation (AF) are among the most common heart rhythm disorders that need medical attention (1). Typical flutter has a macro-reentrant circuit involving cavo-tricuspid isthmus. It can circulate in a clockwise or counterclockwise direction around the tricuspid annulus in the frontal plane. In a counterclockwise typical AFL, the Electrocardiogram (ECG) reveals identically recurring, regular, and saw-tooth flutter waves as well as evidence of continual electrical activity (lack of an isoelectric interval between the flutter waves), often best visualized in the II, III, aVF, and V1 leads. The atrial rate is usually 250 - 350 beats/minute during a typical AFL (1, 2). Ventricular rate depends mainly on the functionality of the Atrioventricular Node (AVN). When there is some disturbance in AVN conduction, the ventricular rhythm may become irregular (flutter with variable block). When the flutter circuit is clockwise or there is an atypical flutter (not involving the cavo-tricuspid isthmus), the electrocardiographic features may be difficult to interpret and may mimic focal Atrial Tachycardias (ATs) or AF (2). AF is a supraventricular arrhythmia characterized electrocardiographically by low-amplitude baseline oscillations (fibrillatory or f waves) and an irregular ventricular rhythm. The f waves have a rate of 300 - 600 beats/minute and are variable in amplitude, shape, and timing (2).

Accurate interpretation of the 12-lead ECG is central to

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atrial tachyarrhythmias diagnosis and management (3-5). RR interval irregularity is one of the main ECG findings that help diagnose AF. Yet, this is non-specific and also present in other atrial tachyarrhythmias (4, 6). Typical AF and AFL are usually easily distinguishable on the surface ECG. However, intermediate forms between AF and AFL exist, such as AF with usually prominent baseline undulations and rapid AFL with variable Atrioventricular (AV) conduction, which are not easily distinguishable (Figure 1). Additionally, some leads appear to show fibrillation, while others resemble flutter. Indeed, sometimes the rhythms seem to shift back and forth within a sample recording (7). Accurate differentiation of AFL from other tachyarrhythmias has important implications for patient care and costs. Similarly, accurate separation of AF from atypical AFL and focal AT is important to guide subsequent therapies, including ablation (8).

2. Objectives

It is probable that monitoring atrial activity during arrhythmias can assist in discriminating them from each other. Trans-Esophageal Echocardiography (TEE) may be a useful tool to visualize and monitor atrial activities. It uses high-frequency sound waves (ultrasound) to make detailed pictures of the heart and the great arteries. Its transducer passes through the mouth, down the throat, and into the esophagus. Because the esophagus is so close to the upper chambers of the heart, very clear images of those heart structures and valves can be obtained. In the recent years, TEE has emerged an accepted tool in the management of patients with AF and AFL by screening the Left Atrial Appendage (LAA) for thrombi and allowing earlier cardioversion (9, 10). LAA ejection flow waves can accurately show atrial contraction patterns and can be used as a method to monitor physical atrial activities. This study aims to compare the LAA ejection flow waves of AFL and AF to determine whether it can serve as a method for differentiation of the two arrhythmias.

3. Patients and Methods

3.1. Patient Population

This cross-sectional study was conducted on 20 patients with AF and 20 ones with AFL who were referred for TEE examination to rule out LAA thrombus before elective electrical cardio-version. Descriptive information, including age, Valvular Heart Disease (VHD), Diabetes Mellitus (DM), Hypertension (HTN), Coronary Artery Disease (CAD), and Congestive Heart Failure (CHF), was obtained. Exclusion criteria were conditions in which the patients had contraindications for TEE examination, including severe coagulopathy, active upper Gastrointestinal (GI) bleeding, esophageal stricture and mass, tracheo-esophageal fistula, esophageal diverticulum or varices, severe cervical arthritis, unstable cardiopulmonary condition, and lack of cooperation.

3.2. Echocardiographic Data Collection and Analysis

TEEs were performed for all patients with echocardiography machines GE vivid E9. ECGs were recorded simultaneously. In order to evaluate the ejection flow waves of LAA, pulsed Doppler sampling volume was laid 1 cm inside the LAA at high esophageal views 90° or 120°. Then, the pattern of LAA ejection flow waves was extracted and defined in terms of rate (numbers per minute), peak velocity (meters per second), and regularity. For each patient, the measurements were done for at least five beats and an average was documented. The relationship between LAA ejection flow waves and QRS waves on ECGs was simultaneously evaluated (Figure 2). The data were analyzed and compared in the AFL and AF groups.

3.3. Statistical Analysis of the Data

The collected data were analyzed using the statistical Package for Social Sciences, version 17.0 (SPSS Inc., Chicago, IL, USA) and were reported as mean and standard deviation (mean ± SD). The two groups were compared using Mann-Whitney U-test. Additionally, Receiver Operating Characteristic (ROC) curves were compared using MedCalc software, version 15.8. $P \leq 0.05$ was considered to be statistically significant. (Ethical approval code: 93-5913)

4. Results

4.1. Demographic Data

The mean age of the patients was higher in the AF group compared to the AFL group. There were also differences between the two groups regarding the frequency of concomitant cardiac disorders. The patients' baseline demographic data have been shown in Table 1.

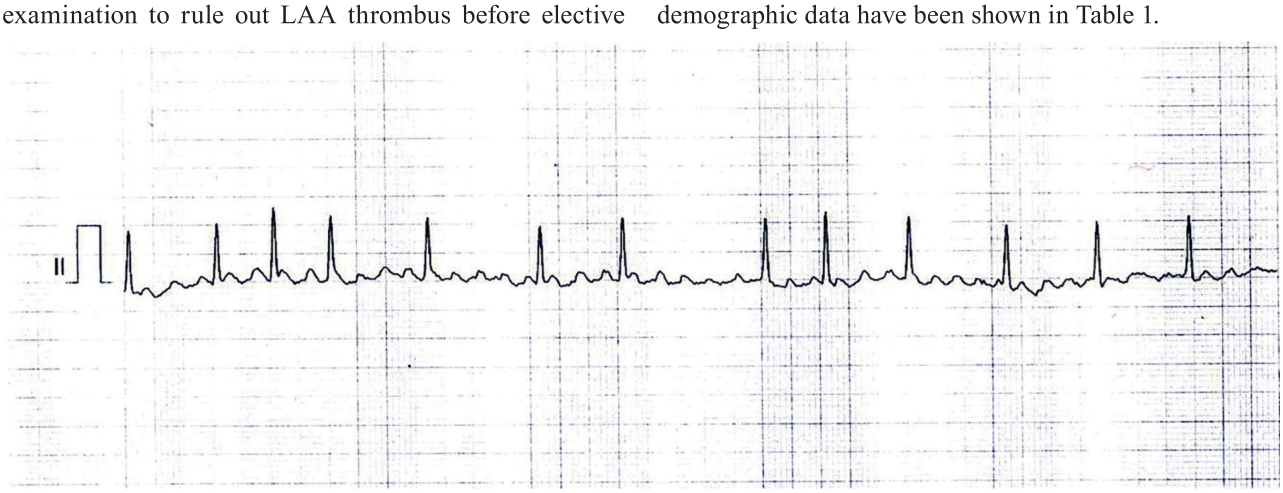

Figure 1. Sometimes, Differentiation of Atrial Flutter with Variable Blocks from Coarse AF Is Difficult

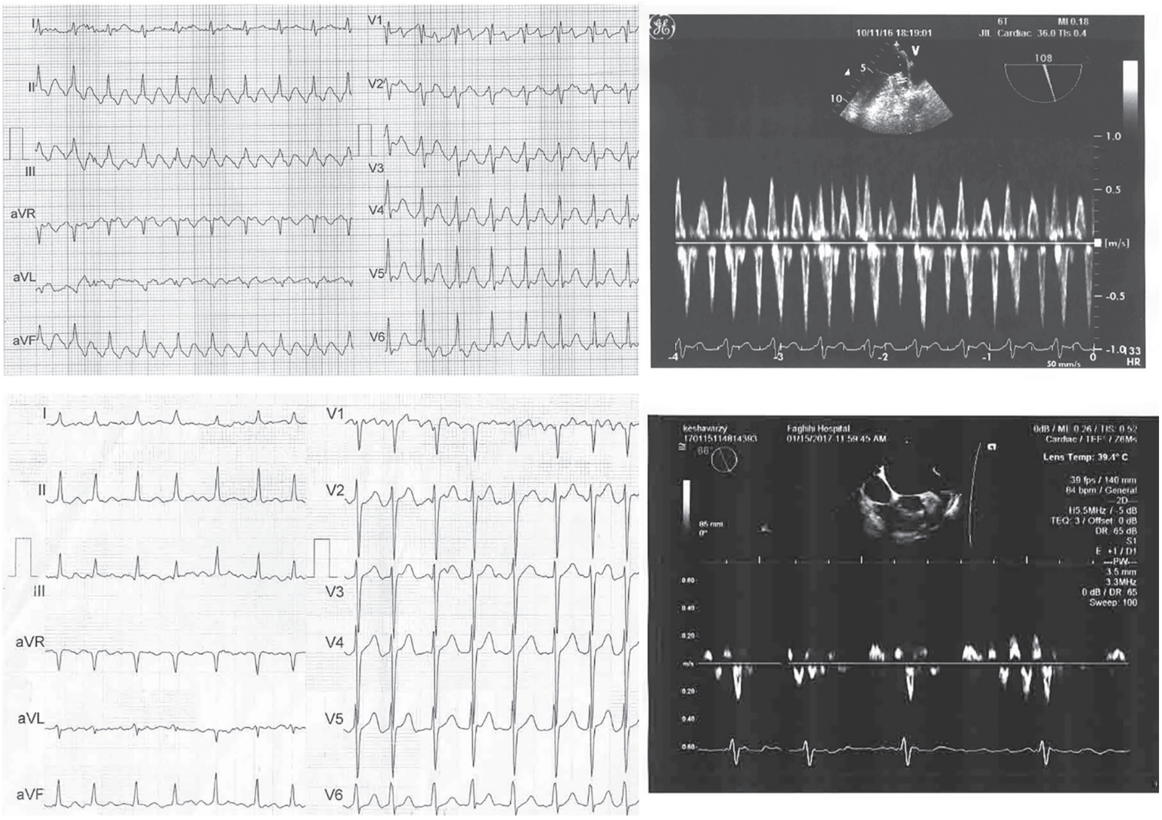

Figure 2. Left Atrial Ejection Flow Wave Patterns during TEE in Typical Atrial Flutter (Top Row) and AF (Bottom Row)

Table 1. Baseline Demographic Data in the AF and AFL Groups

	AF (n = 20)	AFL (n = 20)	P value
Age (years)	69.95 ± 10.45	58.30 ± 8.08	0.02
Female sex (%)	65	60	0.56
Baseline cardiac diseases:			
Valvular heart disease (%)	50	40	0.12
Diabetes mellitus (%)	5	10	0.04
Hypertension (%)	45	35	0.16
Coronary artery disease (%)	5	15	0.02
Heart failure (%)	25	40	0.05

Table 2. Comparison of the AF and AFL Groups Regarding the Velocity and Rate of LAA Ejection Flow Waves

	AF (n = 20)		AFL (n = 20)		P value
	Mean ± SD	Range	Mean ± SD	Range	
Velocity (m/s)	0.172 ± 0.069	0.08 - 0.35	0.302 ± 0.106	0.17 - 0.53	< 0.001
Rate	493.75 ± 50.57	450 - 600	303.50 ± 16.31	280 - 340	< 0.001

4.2. Evaluation of LAA Ejection Flow Waves

AF and AFL groups were compared with respect to the velocity of LAA ejection flow waves. According to Table 2, velocity was significantly higher in the AFL group compared to the AF group (P < 0.001). However, the rate of LAA ejection flow waves was significantly higher in the AF group in comparison to the AFL group (P < 0.001). Moreover, analysis of LAA ejection flow regularity data showed that all patients in the AF group had irregular patterns, while those in the AFL group had regular patterns.

Velocity more than 0.17 m/s had a sensitivity of 95.0% (95% CI, 75.1 - 99.2%), specificity of 70.0% (95% CI, 45.7 - 88.0%), positive predictive value of 76.0%, and negative predictive value of 93.03% for AFL diagnosis (Figure 3). When the proportion of ejection flow waves to QRSs on ECGs was constant, it had a sensitivity of 100.0% (95% CI, 83.0 - 100.0%) and specificity of 80.0% (95% CI, 56.3 - 94.1%) for AFL diagnosis.

5. Discussion

The study results indicated that AFL and AF groups were totally different with respect to velocities and rates of LAA flow waves. The results also demonstrated that a cut-off value of more than 0.17 m/s for velocity might be useful in diagnosis of AFL. This approach might be helpful clinically

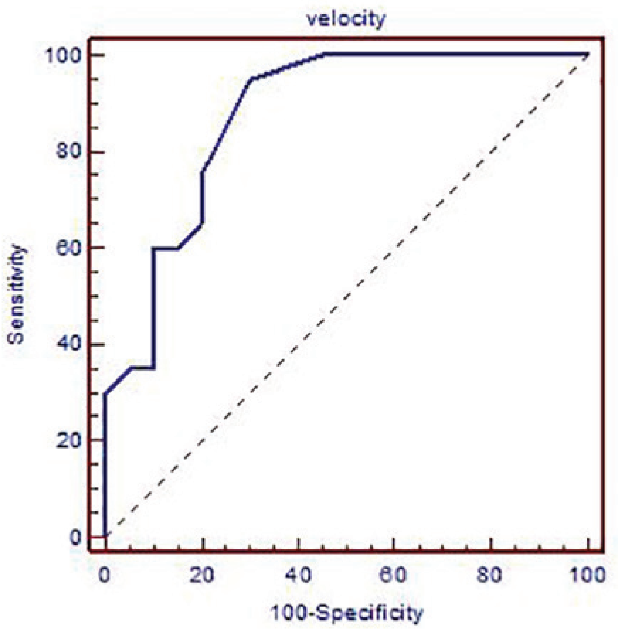

Figure 3. ROC Curve of the Mean LAA Flow Velocity

in AFL diagnosis (Figure 4, Table 3).

Accurate diagnosis of AFL from other atrial tachyarrhythmias like AF has important implications for patient care and costs (11). AFL may cause significant symptoms and serious adverse effects, including embolic stroke, myocardial ischemia, and infarction. However, it is difficult to medically control it (12). Current guidelines recommend catheter ablation without a trial of antiarrhythmic therapy for AFL (8). Misdiagnosis of AFL as AF in the primary care clinic can delay ablation and facilitate the progression of typical AFL to AF (13). Conversely, misdiagnosis of AF as AFL may cause ablation to be attempted without proper planning for a more complex procedure (4).

Because of the widespread use of TEE for detection of thrombus in LAA, the function of LAA as evaluated by pulsed Doppler echocardiography may be an interesting tool to evaluate arrhythmias. However, to the extent of our knowledge, precise comparison of the characterization of the LAA Doppler flow patterns in AF and AFL is missing. Most studies have evaluated LAA in AF. Pollick et al. described LAA patterns in sinus rhythm and AF. It was

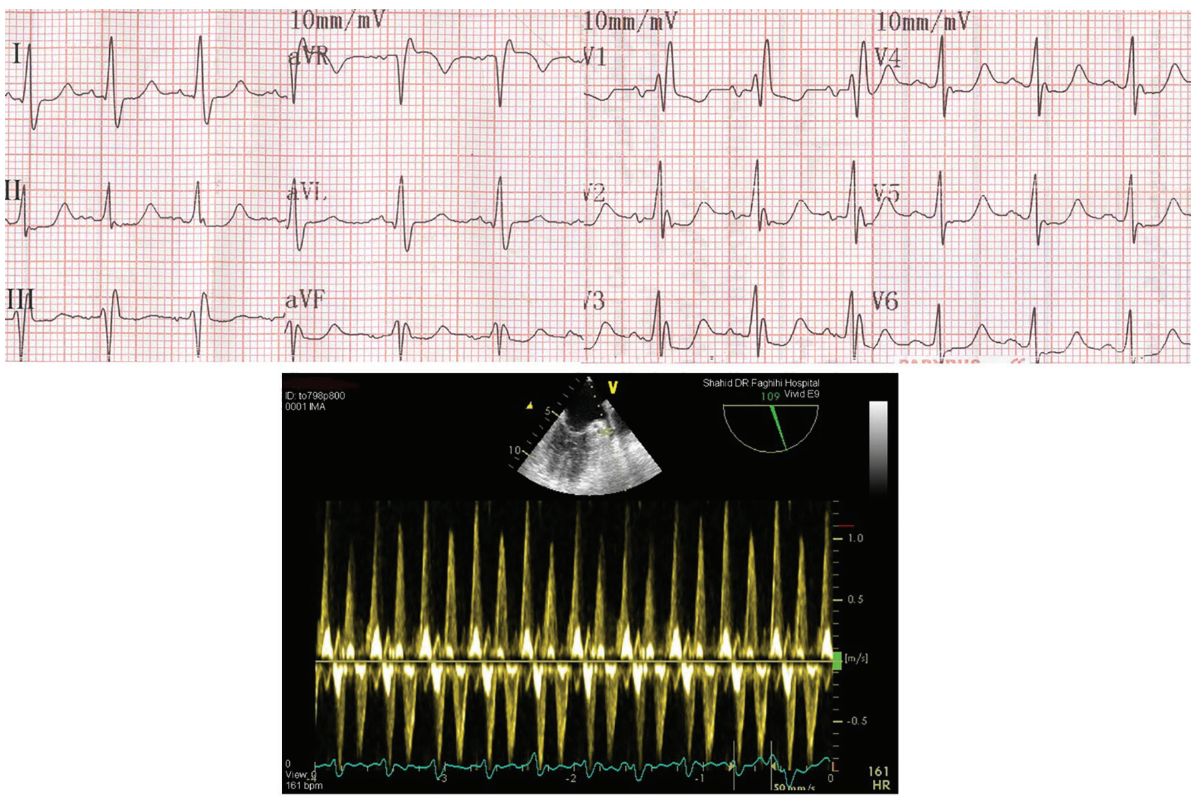

Figure 4. Electrocardiogram of a Patient with Paroxysmal Palpitations (Top). ECG May Mimic Sinus Tachycardia with Right Bundle Branch Block. Left Atrial Ejection Flow Wave Patterns during TEE Were in Favor of Atrial Flutter (Bottom). The Diagnosis Was Further Confirmed with Electrophysiological Studies.

Table 3. Summary of Useful Echocardiographic Findings for Differentiating AF from AFL

	AF	AFL
Median LAA ejection flow wave velocity	0.160	0.300
Median LAA ejection flow wave rate	475	300
LAA ejection flow wave rhythm	Irregular	Regular
Mitral E wave rhythm	Irregular with variable velocities	Regular with constant velocities
Mitral A wave	Absent	Present
Severe MS or MR	Correlated	Not correlated

demonstrated that blood flow ejection velocity in the LAA was correlated to the presence of spontaneous echo contrast, thrombus formation, and risk of systemic embolization (14). Nakagawa et al. showed that patients with coarse AF had higher LAA velocities and lower cerebral embolic events compared to those with fine AF (15). Moreover, the findings of the study by Kamp et al. indicated an increase in the risk of thromboembolic events in patients with low flow velocity in the left atrial appendage (16). Bollman et al. also reported that a low LAA flow velocity was a major hemodynamic determinant for the occurrence of spontaneous echo contrast (17).

In the present study, patients suffering from AFL and AF were compared regarding the rate, velocity, and regularity of LAA ejection flow waves. The results indicated that the maximum ejection velocity was 0.35 and 0.53 m/s in the AF and AFL groups, respectively. The velocity of > 0.17 m/s had a sensitivity of 95.0% (95% CI, 75.1 - 99.2%), specificity of 70.0% (95% CI, 45.7 - 88.0%), positive predictive value of 76.0%, and negative predictive value of 93.03% for diagnosis of AFL. Moreover, AFL and AF patients had characteristic patterns regarding rate and regularity. In the AFL patients, LAA ejection flow waves had an average rate of 303.50 ± 16.31 with regular patterns. However, the AF patients showed irregular LAA ejection flow waves with a rate of 493.75 ± 50.57. When the proportion of ejection flow waves to QRSs on ECGs was constant, it had a sensitivity of 100.0% (95% CI, 83.0 - 100.0%) and specificity of 80.0% (95% CI, 56.3 - 94.1%) for AFL diagnosis.

This research had some limitation. First of all, the two groups were different with regard to the baseline characteristics. However, realistically thinking, it is not possible to find two similar populations for the two arrhythmias as various risk factors induce or precipitate these two conditions. In addition, TEE is an invasive procedure and cannot be routinely applied to all patients as a means to help arrhythmia diagnosis. Consequently, the results of this study are helpful only for patients who have a clinical indication for TEE. Furthermore, AF population has a wide array of LA disorders affected by the duration of arrhythmia and the precipitating cause (18-21). As a result, the present AF population that mostly consisted of paroxysmal patients who needed TEE for cardioversion or evaluation of valvular disease could not provide a true representative of this population. Nevertheless, it should be noticed it was not ethical to perform TEE on all AF patients since many patients do not clinically need the procedure. Hence, the population was a good representative of the patients requiring TEE. Finally, due to the small sample size, the 95% CI was wide.

In conclusion, by examining LAA ejection flow waves, TEE might be helpful for distinction of AFL from AF in patients with clinical indications for TEE. The current study aimed to find an echo sign for distinction of AF from AFL in typical cases. Whether this echo sign is useful for discrimination of AF from AFL in atypical and ambiguous cases needs further investigations.

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Authors' Contribution

Study concept and design: BM and KA; Acquisition of data: BM; Analysis and interpretation of data: AA and BM; Drafting of the manuscript: AA and BM; Critical revision of the manuscript for important intellectual content: AA, BM, and KA; Statistical analysis: AA and BM; Administrative, technical, and material support: KA; Study supervision: KA

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Financial Disclosure

The authors have no financial interests related to the material in the manuscript.

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