Electrocardiographic predictors of early recurrence of atrial fibrillation

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Abstract

Background: Electrical cardioversion (ECV) is an effective method for restoring sinus rhythm after atrial fibrillation (AF). However, early recurrence of AF occurs in a significant number of patients after ECV. This study aimed to identify electrocardiographic (ECG) predictors of early AF recurrence after ECV.

Methods: A total of 272 patients with persistent AF undergoing successful ECV were consecutively enrolled in this study. We investigated clinical, echocardiographic, and ECG data. The 12-lead ECG parameters were measured during sinus rhythm right after ECV using a digital caliper. The early AF recurrence was defined as recurrence within 2 months.

Results: Of the 272 patients, 165 patients (60.7%) experienced an early AF recurrence. Maximum P-wave duration (PWD) in limb leads (OR: 1.086; 95% CI: 1.019–1.157; \( p = .012 \)) and P-terminal force (PTF) in V\(_1\) (OR: 1.019; 95% CI: 1.004–1.033; \( p = .011 \)) were independent predictors of early AF recurrence after ECV. The optimal cutoff value of the maximum PWD in limb leads for predicting early AF recurrence was 134 ms, characterized by 90.3% sensitivity and 72.0% specificity. Likewise, the optimal cutoff value of PTF in V\(_1\) was 50 ms \( \times \) mm, characterized by 80.0% sensitivity and 64.5% specificity.

Conclusion: A longer PWD (>134 ms) and a larger PTF (>50 ms \( \times \) mm) were useful predictors of early recurrence of AF after successful ECV in clinical practice. A more effective rhythm control therapy such as catheter ablation or rate control strategy rather than a repeat ECV should be considered.

KEYWORDS
atrial fibrillation, cardioversion, P-terminal force, P-wave duration, recurrence

1 | INTRODUCTION

Atrial fibrillation (AF) is the most prevalent sustained arrhythmia seen in clinical practice and is associated with high healthcare costs (Delaney et al., 2018; Go et al., 2001). There are two strategies for addressing persistent AF. One approach is to control the ventricular rate using an atrioventricular node blocking agent, and the other is to restore the sinus rhythm (SR) using antiarrhythmic drugs (AADs),...
electrical cardioversion (ECV), and catheter ablation. Rhythm control is performed to improve the quality of life by reducing symptoms such as palpitation, chest pain, and dyspnea, although there is no clear evidence of survival benefit (Wyse et al., 2002). Previous studies reported that the immediate overall success rate for ECV converting AF to SR is up to 90% (Berry et al., 2001; Pisters et al., 2012; Tosso et al., 2012). However, maintenance of SR is often challenging because almost half of the patients return to AF within 1 year post-cardioversion (Tosso et al., 2012). Moreover, most recurrence happens within 1 month after ECV (Bertaglia et al., 2002; Tieleman et al., 1998). Therefore, careful early selection of the therapeutic strategy is crucial to reduce unnecessary medical costs and prevent possible ECV complications.

Various clinical, demographic, and echocardiographic risk factors have been proposed as predictors for AF recurrence after successful ECV. A prolonged AF duration, especially longer than 6 months, was associated with a significant increase of AF recurrence (Tosso et al., 2012). Concerning demographics, older patients have a higher risk of recurrence of AF (Pisters et al., 2012). Besides, multiple comorbidities including hypertension, diabetes, and chronic obstructive pulmonary disease (COPD) have been suggested as independent risk factors that reduce the likelihood of SR maintenance (Berry et al., 2001; Pisters et al., 2012; Soran et al., 2008). Also, several studies have shown that left ventricular (LV) systolic dysfunction and left atrial (LA) enlargement are beneficial for predicting AF recurrence (Marchese et al., 2011; Raitt et al., 2006). Regarding ECG parameters, P-wave duration and dispersion were suggested as ECG predictors of AF recurrence after ECV (Fujimoto et al., 2018; Gonna et al., 2014). However, evidence for these parameters in predicting AF recurrence is still lacking, so these predictors are not commonly used in clinical practice. In addition, these ECG parameters have not been thoroughly evaluated for early recurrence of AF after ECV. We hypothesized that simple ECG predictors could be useful for patients who experience early AF recurrence to determine future treatment strategy including catheter ablation or rate control therapy. This prospective cohort study aimed to identify predictors of early AF recurrence after successful ECV, including clinical, echocardiographic, and especially ECG parameters.

2  \| METHODS

2.1  \| Study population

All consecutive adult patients (≥18 years of age) with symptomatic persistent AF who underwent ECV at the Samsung Medical Center in Korea from November 2017 to October 2019 were enrolled prospectively in this study. This study complied with the Declaration of Helsinki, and the research protocol was approved by the ethics committee of the Samsung Medical Center. We reviewed the medical records, and the clinical, echocardiographic, and electrocardiographic data were investigated. Persistent AF was defined as AF duration over 3 months that did not convert to SR even with at least two kinds of class Ic or class III AADs. Exclusion criteria were as follows: a previous ECV within 1 year, previous AF ablation, moderate-to-severe valvular heart disease, hypertrophic cardiomyopathy, cardiac implantable electrical devices, congenital heart disease, previous cardiac surgery, and thyroid disease.

2.2  \| Electrical cardioversion

All patients undergoing ECV were anticoagulated for at least 1 month before ECV. Transesophageal echocardiography was routinely performed right before the procedure to identify the intracardiac thrombus. ECV was performed under sedation in an electrophysiology laboratory equipped with cardiopulmonary resuscitation devices and under supervision by a cardiologist while the patient had continuous blood pressure, heart rate, and oxygen saturation monitoring. According to our hospital protocol, the first biphasic synchronous shock through self-adhesive electrodes was positioned anterolaterally and delivered at 150J and then increased to 200J if AF persisted. Successful ECV was defined as a case when SR was maintained at least 2 min after ECV without immediate AF recurrence (Fuster et al., 2006).

2.3  \| ECG parameter measurements

Standard 12-lead ECGs were digitally recorded using the CardioLab™ electrophysiology recording system (GE Healthcare) (Figure 1). The P-wave duration (PWD) and amplitude were measured on all 12 leads, and other conventional ECG parameters, including the PR interval, QRS duration, and QT interval, were measured in lead II. The maximum PWD was defined as the longest value for each limb and precordial leads. The P-wave terminal force (PTF) is a product of the amplitude (millimeter) and the duration (millisecond) of the terminal phase of P-wave in lead V1. All ECG parameters were measured with digital calipers with magnification (200%-800%) by two cardiology fellows (JHC, HJK), unaware of the AF recurrence status.

2.4  \| Echocardiographic examination

The transthoracic echocardiography was always performed together with transesophageal echocardiography before ECV. The LA diameter was measured in the M mode parasternal long-axis view with the probe located in the third or fourth intercostal space (Lang et al., 2015). The LA volume index (LAVI) was measured by the biplane area length method using the apical four-chamber and apical two-chamber view at the ventricular end-systole and indexed to the calculated body surface area using the Du Bois formula (Lang et al., 2015). The LV ejection fraction (LVEF) was accessed by the biplane Simpson method at ventricular end-diastole (Lang et al., 2015).

2.5  \| Follow-up after discharge

Clinical follow-up was scheduled monthly until 3 months after ECV. At each visit, recurrence of AF-related symptoms and 12-lead
ECG were obtained. Routine 24-h Holter monitoring was applied 2 months after ECV if no AF-related symptoms were obtained each outpatient visit. Patients who had recurrent AF-related symptoms were evaluated immediately using Holter or event monitoring regardless of follow-up schedule and educated to receive a 12-lead ECG at a nearby hospital as soon as symptoms occur. After 2 months, follow-up visits were planned with ECG and Holter monitoring at 4, 8, and 12 months for patients whose sinus rhythm was maintained. Diagnosis of early AF recurrence was made when AF was confirmed on 12-lead ECG, or AF lasting at least 30 s was documented on Holter monitoring within 2 months after ECV. Time to AF recurrence was calculated from successful ECV to the first AF rhythm documentation on ECG or Holter monitoring after successful ECV.

### Statistical analysis

SPSS statistical software (version 25; SPSS Inc.) was utilized to perform data analysis. Continuous variables are reported as mean values ± SD, and categorical variables as the number of patients (percentage). The chi-square test, Fisher’s exact test, and independent sample t tests were performed to compare the two groups. Univariate and multivariate logistic regression were performed to identify predictors for AF recurrence, and an odds ratio (OR) presented with a 95% confidence interval (CI). For the AF-free survival analysis, a Kaplan–Meier survival curve was performed. Receiver operating characteristic (ROC) analysis was performed to evaluate the optimal cutoff value of the ECG parameters for early recurrence of AF after successful ECV. ROC analysis for the model combining the two parameters was carried out using predicted probability from a logistic regression analysis with two parameters. All statistical tests were two-tailed, and a p-value of <.05 was considered significant.

### RESULTS

#### 3.1 Baseline characteristics

The study flow chart with the number of patients is presented in Figure 2. A total of 380 patients underwent ECV, and 325 patients were successfully converted to SR. The overall ECV success rate was 85.5%. Excluding 48 patients based on exclusion criteria, 277 patients were finally included in this study. Of these 277 patients, 5 patients were lost to follow-up. We divided 272 patients into two...
groups (Group A and Group B) based on the early AF recurrence. At 2 months after ECV, 165 patients (Group A, 60.7%) experienced early AF recurrence, and 107 patients (Group B, 39.3%) maintained the SR. In Group B, only 42 patients (39.3%) experienced AF recurrence during the follow-up period (10.1 ± 6.0 months). The mean time to AF recurrence was significantly different between the two groups (Group A vs. Group B; 30 ± 8 days vs. 260 ± 132 days; \( p < .0001 \)). The baseline demographic, clinical, echocardiographic, and electrocardiographic characteristics of each study group are summarized in Table 1. The mean age was similar in Group A vs. Group B (60 ± 9 years vs. 60 ± 11; \( p = .960 \)). Male sex was dominant in both groups (\( p = .073 \)). Patients with chronic kidney disease were more common in Group B (5.6%) than Group A (0%) (\( p = .003 \)). Most patients in both study groups were taking AADs before (Group A vs. Group B, 82.4% vs. 85.0%, \( p = .570 \)) and after ECV (Group A vs. Group B, 93.9% vs. 97.2%, \( p = .219 \)). 10 (6.1%) patients in Group A and 3 (2.8%) patients in Group B were not taking AADs, due to symptomatic bradycardia. The patients with early AF recurrence were found to be taking more propafenone (Group A vs. Group B, 37.0 vs. 21.5%; \( p = .007 \)) and less amiodarone (Group A vs. Group B, 33.9 vs. 46.7%; \( p = .035 \)) compared with the patients without early AF recurrence.

The mean \( \text{CHA}_2 \text{DS}_2 \text{-VASc} \) score was 1 in both groups, and the distribution of this score was not different between the two groups. There was no significant difference between the two groups in other variables such as comorbidities, LV systolic function, and LA size. More than half of the patients had AF duration longer than 6 months, and over 80% of patients had LA diameter larger than 40 mm in both groups. The maximum PWD in limb leads and precordial lead, duration of PTF, and PTF were strongly associated with early AF recurrence after ECV. Other conventional ECG parameters such as P-wave amplitude, PR interval, QRS duration, and QT interval were not significantly different between groups.

### 3.2 PWD and PTF results as predictors of early AF recurrence

The results of the logistic regression analysis are summarized in Table 2. In univariate analysis, four electrocardiographic parameters...
### TABLE 1 Baseline clinical, echocardiographic, and electrocardiographic characteristics

| Variables                                              | Group A \(n = 165\) | Group B \(n = 107\) | \(p\)-value |
|--------------------------------------------------------|-----------------------|----------------------|-------------|
| **Demographic variables**                              |                       |                      |             |
| Age, years                                             | 60 ± 9                | 60 ± 11              | .960        |
| Age >65 years, n (%)                                    | 43 (26.1)             | 34 (31.8)            | .307        |
| Male, n (%)                                            | 138 (83.6)            | 80 (74.8)            | .073        |
| BMI, kg/m²                                             | 25.9 ± 2.7            | 26.0 ± 3.3           | .785        |
| CHA2DS2-VASc score                                     | 0.98 ± 0.87           | 1.04 ± 0.76          | .589        |
| CHA2DS2-VASc score ≥2, n (%)                           | 37 (22.4)             | 29 (27.1)            | .379        |
| Previous ECV, n (%)                                     | 8 (4.8)               | 7 (5.9)              | .550        |
| AF duration, months                                    | 23 ± 33               | 21 ± 32              | .499        |
| AF duration >6 months, n (%)                           | 84 (50.9)             | 54 (50.5)            | .943        |
| AF duration >12 months, n (%)                          | 71 (43.0)             | 38 (35.5)            | .217        |
| AF duration >24 months, n (%)                          | 52 (31.5)             | 29 (27.1)            | .437        |
| **Medical history**                                    |                       |                      |             |
| Hypertension, n (%)                                     | 89 (53.9)             | 64 (59.8)            | .340        |
| Diabetes, n (%)                                         | 34 (20.6)             | 15 (14.0)            | .167        |
| Chronic kidney disease, n (%)                          | 0                     | 6 (5.6)              | .003        |
| Coronary artery disease, n (%)                         | 1 (0.6)               | 1 (0.9)              | 1.000       |
| Stroke/transient ischemic attack, n (%)                 | 11 (6.7)              | 3 (2.8)              | .159        |
| **Antiarrhythmic drugs before cardioversion, n (%)**    | 136 (82.4)            | 91 (85.0)            | .570        |
| Flecainide, n (%)                                       | 18 (10.9)             | 15 (14.0)            | .443        |
| Propafenone, n (%)                                      | 58 (35.2)             | 23 (21.5)            | .016        |
| Amiodarone, n (%)                                       | 50 (30.3)             | 47 (43.9)            | .022        |
| Dronedarone, n (%)                                      | 10 (6.1)              | 4 (3.7)              | .397        |
| Sotalol, n (%)                                          | 0                     | 2 (1.9)              | .154        |
| Pilsicainide, n (%)                                     | 0                     | 0                    |             |
| **Antiarrhythmic drugs after cardioversion, n (%)**     | 155 (93.9)            | 104 (97.2)           | .219        |
| Flecainide, n (%)                                       | 24 (14.5)             | 20 (18.7)            | .364        |
| Propafenone, n (%)                                      | 61 (37.0)             | 23 (21.5)            | .007        |
| Amiodarone, n (%)                                       | 56 (33.9)             | 50 (46.7)            | .035        |
| Dronedarone, n (%)                                      | 14 (8.5)              | 8 (7.5)              | .766        |
| Sotalol, n (%)                                          | 0                     | 2 (1.9)              | .154        |
| Pilsicainide, n (%)                                     | 0                     | 1 (0.9)              | .393        |
| **Echocardiographic parameters**                        |                       |                      |             |
| LVEF, %                                                 | 57.9 ± 8.6            | 56.5 ± 10.4          | .251        |
| LA diameter, mm                                         | 45.9 ± 7.3            | 46.6 ± 5.8           | .425        |
| LA diameter >40 mm, n (%)                               | 144 (87.3)            | 90 (84.1)            | .463        |
| LAVI, ml/m³                                             | 52.1 ± 15.1           | 51.5 ± 16.8          | .772        |
| **Electrocardiographic parameters**                     |                       |                      |             |
| Maximum PWD in limb leads, ms                          | 148 ± 14              | 136 ± 14             | <.001       |
| Maximum PWD in precordial leads, ms                    | 146 ± 15              | 134 ± 15             | <.001       |
| Duration of P-terminal forced, ms                      | 80 ± 16               | 67 ± 16              | <.001       |
| P-terminal force, ms × mm                              | 74.9 ± 33.2           | 49.4 ± 26.3          | <.001       |
| Maximum P-wave amplitude in limb leads, mV              | 0.15 ± 0.05           | 0.16 ± 0.06          | .396        |
| PR interval, ms                                         | 199 ± 35              | 194 ± 33             | .277        |
| QRS duration, ms                                        | 93 ± 15               | 93 ± 16              | .882        |
| QT interval, ms                                         | 425 ± 37              | 435 ± 50             | .093        |
| Corrected QT interval, ms                              | 419 ± 35              | 423 ± 42             | .419        |

Note: Variables are expressed as n (%) or mean ± SD.

Abbreviations: AF, atrial fibrillation; BMI, body mass index; CHA2DS2-VASc score, congestive heart failure, hypertension, age ≥75 years, diabetes mellitus, prior stroke or transient ischemic attack or thromboembolism, vascular disease, age 65–74 years, sex category; ECV, electrical cardioversion; LA, left atrium; LAVI, left atrial volume index; LVEF, left ventricular ejection fraction; PWD, P-wave duration.
were strongly associated with early recurrence of AF: the maximum PWD measured in the limb and precordial leads, duration of PTF, and P-terminal force. After multivariate analysis using variables with \( p < .2 \) in univariate analysis, only maximum PWD in limb leads \( (\text{OR: } 1.086; \text{95\% CI: } 1.019-1.157; \ p = .012) \) and PTF \( (\text{OR: } 1.019; \text{95\% CI: } 1.004-1.033; \ p = .011) \) were independent predictors of early AF recurrence after adjusting for age, sex, diabetes, stroke (or transient ischemic attack), propafenone, amiodarone, and QT interval. Each millisecond increase in the maximum PWD in limb leads and each millisecond \( \times \) millimeter increased in the PTF were associated

## Table 2. Univariate and multivariate predictors of early AF recurrence

| Variables                                      | Univariate analysis | Multivariate analysis |
|------------------------------------------------|---------------------|-----------------------|
|                                                | OR | 95% CI | \( p \)-value | OR | 95% CI | \( p \)-value |
| Demographic variables                          |    |        |              |    |        |              |
| Age, per year                                   | 0.999 | 0.975-1.024 | .959 | 0.983 | 0.951-1.015 | .296 |
| Male sex                                        | 1.725 | 0.946-3.144 | .075 | 1.343 | 0.620-2.910 | .455 |
| BMI, per kg/m\(^2\)                             | 0.989 | 0.915-1.069 | .779 |       |          |          |
| CHA\(^2\)DS\(^2\)-VASc score, per 1 point      | 0.922 | 0.687-1.237 | .587 |       |          |          |
| CHA\(^2\)DS\(^2\)-VASc score ≥2,               | 0.777 | 0.443-1.363 | .380 |       |          |          |
| Previous ECV                                    | 0.728 | 0.256-2.070 | .551 |       |          |          |
| AF duration, per month                          | 1.003 | 0.995-1.010 | .499 |       |          |          |
| >6 months                                       | 1.018 | 0.626-1.656 | .943 |       |          |          |
| >12 months                                      | 1.372 | 0.830-2.265 | .217 |       |          |          |
| >24 months                                      | 1.238 | 0.723-2.120 | .437 |       |          |          |
| Medical history                                 |    |        |              |    |        |              |
| Hypertension                                    | 0.787 | 0.481-1.288 | .340 |       |          |          |
| Diabetes                                        | 1.592 | 0.820-3.091 | .170 | 1.558 | 0.718-3.380 | .262 |
| Coronary artery disease                         | 0.646 | 0.040-10.445 | .759 |       |          |          |
| Stroke/transient ischemic attack                | 2.476 | 0.674-9.091 | .172 | 3.343 | 0.834-13.393 | .088 |
| Antiarrhythmic drugs after ECV                  |    |        |              |    |        |              |
| Flecainide                                      | 0.740 | 0.386-1.419 | .365 |       |          |          |
| Propafenone                                     | 2.142 | 1.225-3.747 | .008 | 1.472 | 0.679-3.193 | .327 |
| Amiodarone                                      | 0.586 | 0.356-0.964 | .035 | 1.047 | 0.524-2.091 | .897 |
| Dronedarone                                     | 1.147 | 0.464-2.836 | .766 |       |          |          |
| Echocardiographic parameters                    |    |        |              |    |        |              |
| LVEF, per percent                               | 1.015 | 0.989-1.042 | .251 |       |          |          |
| LA diameter, per mm                             | 0.985 | 0.949-1.022 | .425 |       |          |          |
| LA diameter >40 mm                              | 1.295 | 0.649-2.586 | .463 |       |          |          |
| LAVI, per ml/m\(^2\)                            | 1.002 | 0.987-1.018 | .771 |       |          |          |
| Electrocardiographic parameters                 |    |        |              |    |        |              |
| Maximum PWD in limb leads, per ms               | 1.079 | 1.053-1.106 | <.001 | 1.086 | 1.019-1.157 | .012 |
| Maximum PWD in precordial leads, per ms         | 1.061 | 1.039-1.083 | <.001 | 0.979 | 0.929-1.032 | .436 |
| Duration of PTF, per ms                         | 1.060 | 1.039-1.081 | <.001 | 1.003 | 0.970-1.037 | .855 |
| PTF, per ms \( \times \) mm                     | 1.032 | 1.021-1.043 | <.001 | 1.019 | 1.004-1.033 | .011 |
| Maximum P-wave amplitude in limb leads, per mV  | 0.137 | 0.001-13.464 | .396 |       |          |          |
| PR interval, per ms                             | 1.004 | 0.997-1.011 | .277 |       |          |          |
| QRS duration, per ms                            | 0.999 | 0.983-1.015 | .882 |       |          |          |
| QT interval, per ms                             | 0.995 | 0.989-1.001 | .075 | 0.995 | 0.987-1.003 | .234 |
| Corrected QT interval, per ms                   | 0.997 | 0.991-1.004 | .418 |       |          |          |

Abbreviations: AF, atrial fibrillation; BMI, body mass index; CHA2DS2-VASc score, congestive heart failure, hypertension, age ≥75 years, diabetes mellitus, prior stroke or transient ischemic attack or thromboembolism, vascular disease, age 65–74 years, sex category; ECV, electrical cardioversion; LA, left atrium; LAVI, left atrial volume index; LVEF, left ventricular ejection fraction; PTF, P-terminal force; PWD, P-wave duration.
with an 8.6% and 1.9% increase in the risk of early AF recurrence, respectively.

In Figure 3, the ROC curve for the maximum PWD in limb leads (Figure 3a) and PTF (Figure 3b) are presented, in addition to a model combining the two predictors (Figure 3c). The area under the ROC curve of maximum PWD in limb leads for early AF recurrence was 0.794 (95% CI: 0.732–0.855; \( p < .001 \)) and that for PTF was 0.745 (95% CI: 0.685–0.806; \( p < .001 \)); the model combining the two predictors was 0.814 (95% CI: 0.756–0.871; \( p < .001 \)). Table 3 shows independent predictors with optimal cutoff value and measures of diagnostic accuracy. The optimal cutoff value using the Youden index of the maximum PWD in limb leads to predict early AF recurrence was 134 ms, characterized by 90.3% sensitivity and 72.0% specificity. Likewise, the optimal cutoff value of PTF was 50 ms \( \times \) mm, characterized by 80.0% sensitivity and 64.5% specificity. Maximum PWD in limb leads showed better diagnostic performance than PTF, but there was no significant difference between the two predictors when analyzed using Delong’s test (\( p = .132 \)). The specificity of the model combining the two predictors was 75.7%, which was better than that of the two predictors. A detailed explanation of the model combining the two predictors is in supplementary material.

### 3.3 | Intra- and inter-rater reliability of measurements

The intra- and inter-rater correlation coefficients for maximum PWD in limb leads were 0.941 and 0.932, respectively. The intra- and inter-rater correlation coefficients for the P-terminal force were 0.957 and 0.935, respectively. There was no disagreement on the presence of early recurrence between raters.

### 4 | DISCUSSION

In our study, we aimed to identify ECG predictors for early AF recurrence after successful ECV. The results of this study suggest that two ECG parameters, maximum PWD and PTF, could be useful for predicting early AF recurrence after successful ECV. In particular, the maximum PWD in limb leads with a cutoff value of 134 ms showed the highest sensitivity, and the model combining the two predictors showed the highest specificity for predicting early AF recurrence.

The overall recurrence rate of AF within 1 month after ECV in this study was approximately 55%, which was similar to previous studies (Bertaglia et al., 2002; Tieleman et al., 1998). The current study included a large number of patients at higher risk of AF recurrence. AF duration was longer than 6 months in more than half of these patients, and the LA dimension was greater than 40 mm in over 80% of patients. Prediction of early recurrence of AF after ECV would be necessary, especially in patients with a high risk of AF recurrence, to guide future treatment strategies. 12-lead ECG is a simple, inexpensive, and reproducible examination method routinely performed in AF patients. Therefore, prediction of early recurrence using ECG parameters would be beneficial in real-world clinical practices. In the AFFIRM study, the authors suggested that a history of coronary artery disease (OR: 0.52; 95% CI: 0.35–0.76; \( p = .001 \)) and a PWD longer than 135 ms (OR: 1.60; 95% CI: 1.11–2.31; \( p = .001 \)) were predictors for AF recurrence within 2 months after ECV (Raitt et al., 2006). However, the PWD was only measured in lead II in this study. In a prospective study that involved 77 patients, Gonna et al. also showed that the maximum PWD in 12 leads could predict AF recurrence after ECV (OR: 3.17; 95% CI: 1.16–8.67; \( p = .02 \)). A maximum PWD longer than 142 ms was suggested as an optimal cutoff point (sensitivity 58.6%, specificity 62.1%) (Gonna et al., 2014). In our study, we showed that maximum PWD is a good predictor for AF recurrence after ECV, and these results are consistent with those of a previous study. Besides, we propose PTF as a new predictor of early AF recurrence after successful ECV. PTF showed comparable diagnostic accuracy compared with maximum PWD in limb leads. Along with these results, the model combining these two predictors showed better specificity to predict early recurrence of AF after ECV.

The PWD, which was a significant predictor in this study, represents the atrial conduction time. Since right atrial depolarization...
parameters, it is possible that a small measurement error created a
statistically significant change. To minimize measurement error, we performed tests for intra- and inter-observer reliability. Third, AF recurrence might be underestimated because continuous ECG monitoring was not performed during the follow-up period. Fourth, it may be difficult to apply the cutoff value of ECG parameters to patients with normal LA diameter or shorter AF duration because our findings came from patients with long AF duration and large LV size.

5 | CONCLUSIONS

Maximum PWD in limb leads and PTF in V1 could be useful for predicting early recurrence of AF after successful ECV in clinical practice. An AF patient with a longer PWD and larger PTF on SR ECG should be observed closely after successful ECV even with various AADs. A more effective rhythm control therapy such as catheter ablation or rate control strategy rather than a repeat ECV should be considered in these patients.

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CONFLICT OF INTEREST
None.

AUTHOR CONTRIBUTIONS
J.H.Choi., S.J.Park., and K.M.Park. involved in conceptualization; J.H.Choi., H.J.Kwon., and H.R.Kim. investigated the study; J.H.Choi. and K.M.Park. formally analyzed the study; J.H.Choi. involved in original draft preparation; J.S.Kim., Y.K.On., S.J.Park., and K.M.Park. reviewed and edited the study; J.H.Choi. visualized the study; K.M.Park involved in supervision.

ETHICAL APPROVAL
This study complied with the Declaration of Helsinki, and the research protocol was approved by the local institutional ethics board (Samsung Medical Center Institutional Review Board).

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

### Table 3: Optimal cutoff value and measures of diagnostic accuracy

| Parameters                        | AUC   | Cut-off value | Sen (%) | Spe (%) | PPV (%) | NPV (%) | ACC (%) |
|-----------------------------------|-------|---------------|---------|---------|---------|---------|---------|
| Maximum PWD in limb leads         | 0.794 | 134 ms        | 90.3    | 72.0    | 83.2    | 82.8    | 83.1    |
| P-terminal force                  | 0.745 | 50 ms × mm    | 80.0    | 64.5    | 77.7    | 67.7    | 73.9    |
| Model combining the two predictors| 0.814 | 81.8          | 75.7    | 83.9    | 73.0    | 79.4    |

Abbreviations: ACC, accuracy; AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value; PWD, P-wave duration; Sen, sensitivity; Spe, specificity.
J. E., Corley, S. D., Atrial Fibrillation Follow-up Investigation of Rhythm Management (AFFIRM) Investigators (2002). A comparison of rate control and rhythm control in patients with atrial fibrillation. *New England Journal of Medicine*, 347(23), 1825–1833. https://doi.org/10.1056/NEJMoa021328

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.

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