

## Original Article

# *Electrocardiographic and Demographic Characteristics of Premature Ventricular Contractions With Unsuccessful Ablation*

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## ABSTRACT

**Background:** Premature ventricular contractions (PVCs) are the most common arrhythmia observed in ECGs. Analyzing PVC patterns in ECGs aids in identifying types with a higher likelihood of unsuccessful ablation. This study aimed to investigate the ECG and demographic characteristics of these PVCs.

**Methods:** This study included all patients with PVCs who were hospitalized and underwent unsuccessful ablation at the Rajaie Cardiovascular Medical and Research Institute between 2017 and 2022. ECG results were compared, and PVC patterns in different types were identified.

**Results:** The study comprised 80 patients, ranging from 17 to 79 years of age, with a male predominance of 63% and a female representation of 37%. The most frequently observed locations for PVCs were the left ventricular summit (n = 27 [34%]), the right ventricular outflow tract (n = 13 [9.3%]), papillary muscles (n = 7 [9%]), the great cardiac vein (n = 6 [8%]), the mitral and tricuspid annulus (n = 5 [6%]), the aortomitral continuity (n = 3 [4%]), the fascicle (n = 3 [4%]), and the mid-myocardial part (n = 3 [4%]). Almost all patients (96.3%) experienced symptoms, and the average ejection fraction was 39.2%. Regarding transition location, 50% occurred in lead V<sub>3</sub> (the gray zone). Additionally, 32.5% of the patients demonstrated late transition, 3% showed early transition, and the remaining subjects exhibited positive concordance. Another parameter, breakthrough, was observed in 56% of patients.

**Conclusions:** In this study, the left ventricular summit was identified as the most common site for unsuccessful PVC ablation. This finding highlights the importance of precise electroanatomic mapping during the ablation process. Furthermore, a notable pattern observed in cases of unsuccessful PVC ablation was the breakthrough pattern, suggesting that this pattern could serve as a potential predictor for the success of the ablation procedure. (*Iranian Heart Journal 2025; 26(1): 27-34*)

**KEYWORDS:** Ventricular tachycardia, PVC, Unsuccessful ablation, Electrocardiographic

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Premature ventricular contractions (PVCs) are frequently detected in individuals undergoing long-term Holter monitoring. Numerous factors, such as advanced age, greater height, increased blood pressure, pre-existing heart conditions, sedentary lifestyle, and smoking, have been linked to a higher occurrence of PVCs.<sup>1</sup> While the precise etiology of PVCs remains unclear, potential underlying mechanisms have been proposed, which include triggered activity, automaticity, and reentry.<sup>2</sup> Echocardiography is recommended, particularly in cases of symptomatic PVCs or those with a high PVC burden. Cardiac magnetic resonance imaging can be beneficial in assessing structural heart disease.<sup>2</sup> Holter monitoring is crucial to determining the frequency of PVCs. Nonetheless, predicting outcomes in individuals with PVCs remains a challenge due to the lack of clarity surrounding predictors of adverse outcomes. A higher PVC frequency has been linked to an increased risk of heart failure and mortality. Notably, the observation of improved systolic function following successful PVC ablation indicates a possible cause-effect relationship.<sup>3</sup> While catheter ablation is the most efficient technique for PVC elimination, it comes with certain inherent risks. Conducting primary research to identify individuals susceptible to cardiomyopathy due to PVCs and exploring preventive and therapeutic strategies is of utmost importance. By doing so, the effectiveness of interventions can be maximized. While medical treatment seeks to alleviate the PVC burden and manage associated symptoms, catheter ablation focuses on targeting and eliminating the abnormal cells responsible for generating clinical PVCs.<sup>4</sup> A recent cohort study reported an overall success rate of 84% for catheter ablation in patients; nevertheless, specific anatomical sites can pose challenges during the ablation process.<sup>5</sup> Ablation of

PVCs originating from the left ventricular (LV) summit or crux may be particularly difficult due to various factors, such as restricted access, inadequate power delivery, or the proximity of coronary vessels. Additionally, the deep location of intracavitary structures like LV papillary muscles can impact catheter stability during the procedure.<sup>6</sup> In situations where anatomical challenges are present, ancillary tools such as intracardiac echocardiography, irrigated tip catheters, and epicardial access can be valuable resources. While antiarrhythmic drugs have traditionally been significant in the initial management of PVCs, radiofrequency catheter ablation (RFCA) presents a safe and potentially curative alternative treatment option for cases that do not respond well to medication. Despite advancements in electroanatomical mapping and ablation technology contributing to a high success rate for RFCA (approximately 80%–90%), recurrence and failure rates remain variable. Notably, the ECG features of unsuccessful ablation in idiopathic PVCs have yet to be thoroughly investigated.<sup>7</sup> Due to the complex anatomical structure surrounding the right ventricular outflow tract (RVOT), targeting adjacent structures such as the aorta, the great cardiac vein/anterior interventricular vein and the subvalvular structures in the LV endocardium may be a viable approach in patients who have experienced failed RVOT ablation.<sup>8</sup> Currently, several ECG algorithms have been developed to predict the origin of ventricular arrhythmias by analyzing QRS morphology. These algorithms can provide valuable guidance in clinical decision-making prior to intracardiac mapping and ablation procedures.<sup>9</sup> Despite the advancements in targeting multiple anatomical structures near the RVOT, reports indicate that some ventricular arrhythmias may remain unresponsive to intracardiac and/or epicardial interventions.<sup>10</sup>

Accordingly, the primary objective of this study was to investigate the ECG and demographic features associated with PVCs that have undergone unsuccessful ablation.

## METHODS

This cross-sectional study aimed to investigate the ECG and demographic characteristics of idiopathic PVCs after initial unsuccessful ablation. The study included patients who had undergone PVC ablation at the Rajaie Cardiovascular Medical and Research Institute between 2017 and 2022 and had experienced initial unsuccessful ablation.

Patients were analyzed based on demographic characteristics, PVC type, and left ventricular ejection fraction (LVEF). Patients were included in the study if they met the following criteria: a confirmed diagnosis of PVCs and a history of unsuccessful ablation. Individuals were excluded from the study if they had undergone successful ablation or exhibited more than 1 focus of arrhythmia based on ECG findings. Data management and analysis were performed using IBM SPSS Statistics 24. For quantitative variables, central tendency measures (the mean) and dispersion measures (the standard deviation) were employed. On the other hand, frequencies and percentages were utilized to analyze qualitative variables. The  $\chi^2$  test was used to analyze the relationship between qualitative variables. The independent sample *t*-test was employed to compare quantitative variables with a normal distribution. In cases where the distribution was non-normal, the Mann-Whitney *U* test was utilized. A significance level of 0.05 was established as the threshold for all statistical tests.

## RESULTS

This study included 80 patients who had undergone unsuccessful PVC ablation. The

cohort consisted of 51 male and 29 female patients, with an average age of  $46 \pm 15.5$  years. Further details regarding the demographic characteristics of the participants are presented in Table 1.

**Table 1:** Demographic Characteristics of the Study Population

Variable	Patients (n=80)
Age, y	46±15.5
Left ventricular ejection fraction, %	39.2±13.6
Sex (male)	51 (63.7%)
Diabetes mellitus	9(11.3%)
Hypertension	28(35%)
Smoking	19(23.8%)
Symptom	77(96.3%)

Table 2 provides a comprehensive overview of the frequency and percentage of each PVC site associated with unsuccessful ablation. According to the data presented, the LV summit had the highest percentage, followed by the RVOT and papillary muscles.

**Table 2:** Sites of the Origins of Predominant PVCs

Sites of the Origins of Predominant PVCs	N (%)
Summit	27 (34%)
RVOT	13 (16%)
Papillary muscles	7 (9%)
Para Hisian	7 (9%)
GCV	6 (8%)
Rings	5 (6%)
Fascicle	3 (4%)
AMC	3 (4%)

PVCs: premature ventricular contractions, RVOT: right ventricular outflow tract, GCV: the great cardiac vein, AMC: the aortic mitral continuity

Figure 1 illustrates the ECG characteristics of PVCs across various ECG leads. Among leads II, III, and AVF, the monophasic R demonstrated the highest value. In contrast, the lowest value in all 3 leads was associated with  $R/S > 1$ . Figure 2 depicts the ECG characteristics of the lateral leads, specifically leads I, AVL, and AVR. In leads I and AVL, the most frequently observed patterns were QS, monophasic R, and  $R/S <$

1. Conversely, lead AVR exhibited the highest prevalence of QS, QR, and monophasic R patterns. Figure 3 illustrates the ECG characteristics of leads V<sub>1</sub> and V<sub>2</sub>. In lead V<sub>1</sub>, the most prevalent pattern was

R/S < 1, followed by QS and monophasic R. On the other hand, lead V<sub>2</sub> demonstrated the highest occurrence of R/S < 1, with monophasic R and R/S > 1 being the next most common patterns.

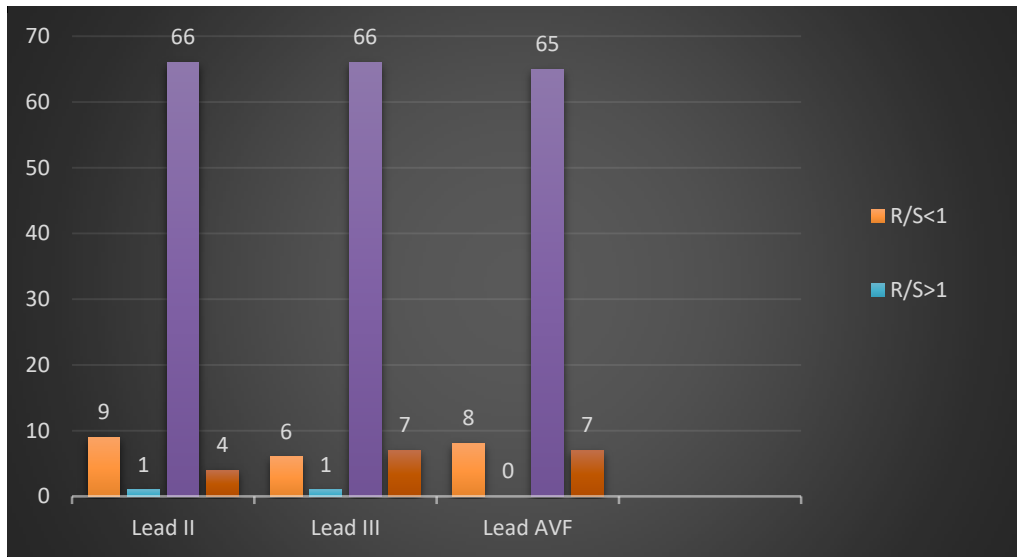


Figure 1: The image showcases the ECG characteristics of the inferior leads.

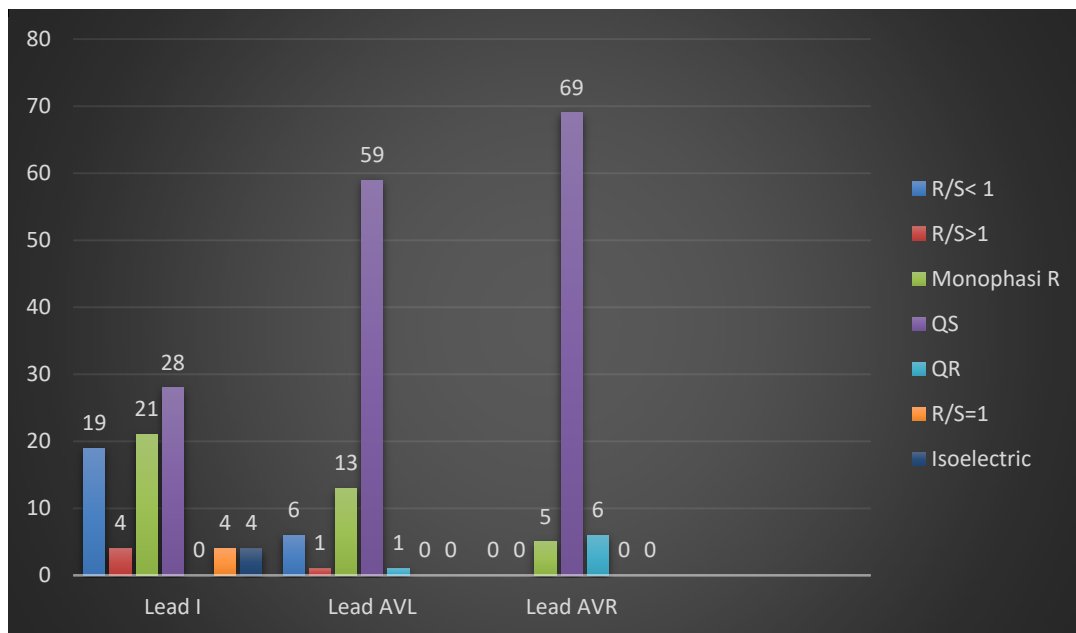
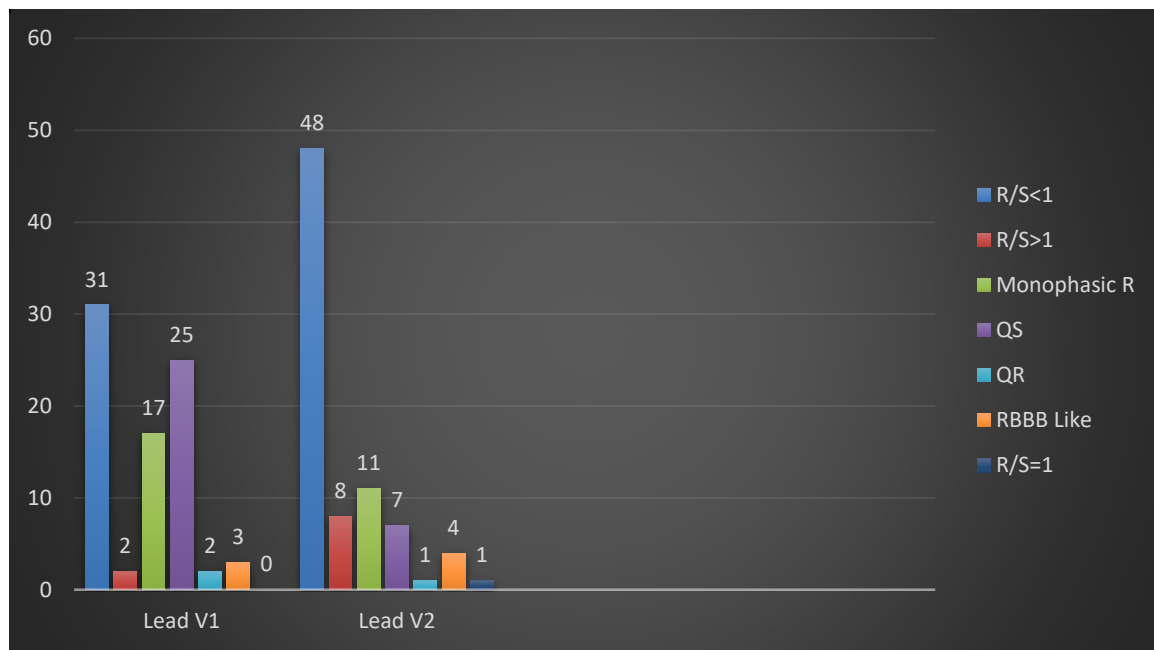


Figure 2: The image shows the ECG characteristics of the lateral leads.



**Figure 3:** The image illustrates the ECG characteristics of leads V<sub>1</sub> and V<sub>2</sub>.

The distribution of transition patterns in the studied PVCs was highest for the gray zone, late transition, positive concordance transition, and early transition. Additionally, among the breakthrough pattern distribution, 56% were categorized as breakthrough +, while the remaining 44% were classified as breakthrough -.

## DISCUSSION

Recent studies indicate that RFCA may be a safer and more effective therapeutic option for patients with PVCs.<sup>11</sup> Despite the improvements in mapping technology and ablation techniques, there have been variable rates of recurrence and failure. To address these issues, it is crucial to focus on enhancing the identification of PVC anatomical origin, optimizing the selection of ablation catheters, refining ablation approaches, and ensuring precise targeting of the desired location. By addressing these aspects, the success rates of RFCA procedures can be improved, and the likelihood of recurrence can be reduced.<sup>12</sup> Large-scale international studies on

idiopathic PVC ablation have revealed that PVCs originating from the epicardium or those with multiple foci are associated with a higher likelihood of ablation failure.<sup>13</sup> Conversely, PVCs arising from the RVOT have been associated with the highest success rate and the lowest complication rate, establishing the RVOT origin as a significant predictor of long-term procedural success.<sup>8</sup>

The present retrospective descriptive study analyzed 80 patients who had experienced unsuccessful ablation. The mean age of these patients was 46.5 years, aligning with the findings of similar studies. The patients' mean LVEF was reported as 39.2, which appears to be lower than that of patients with successful ablation. In terms of demographic characteristics, 63% of the participants were male, 9 had diabetes mellitus, 28 had a history of hypertension, and 19 were either current or former smokers. Furthermore, a notable finding was that 96% of the patients exhibited symptoms.

Studies have indicated that patients with hypertension are more prone to late recurrence, yet the exact reason for this remains unknown. One potential explanation

is that hypertension could be linked to increased anxiety in these patients. However, it is still unclear whether optimal blood pressure control can help mitigate PVC recurrence.<sup>12,14</sup> The current study analyzed the ECG and demographic characteristics of PVCs that had undergone unsuccessful ablation. Interestingly, patient age did not demonstrate a significant association with ablation success, implying that older age alone may not be a reliable predictor of ablation failure. On the other hand, a significant difference in LVEF was observed between the successful and unsuccessful ablation groups, suggesting that a lower LVEF could be a contributing factor to the increased likelihood of ablation failure. Unlike hypertension, the presence of diabetes mellitus did not show a significant difference between the successful and unsuccessful ablation groups. Nonetheless, the rate of smoking was notably higher in the unsuccessful ablation group, and this difference was statistically significant. Concerning the origin site of the PVCs under investigation, the LV summit emerged as the most frequently identified location, accounting for 27 cases. The second most common site was the RVOT, observed in 13 patients. Other locations, including the papillary muscles, para Hisian region, great cardiac vein, mitral ring, tricuspid ring, and aortic mitral continuity, were also noted as sites of PVC origins, albeit with a lower prevalence rate. Moreover, previous research has identified various predictors for the ECG outcomes of radiofrequency ablation. According to studies conducted by Vestal et al,<sup>15</sup> morphological changes in QRS, wider QRS width, and higher R-wave amplitude in lead II are predictors for unsuccessful radiofrequency ablation of RVOT PVCs. Further, the presence of morphological changes in the QRS of RVOT PVCs has been established as the sole predictor for ECG recurrence.<sup>16</sup> In terms of the ECG characteristics observed in the inferior leads, monophasic R morphology was

found to be the most prevalent. This finding can be attributed to the higher frequency of PVCs originating from the LV summit and RVOT, known to display this particular morphology. Notably, in lead II, 9 patients exhibited  $R/S < 1$ , while in leads III and AVF, this number was 6 and 8, respectively. Other morphologies were infrequently observed in the inferior leads. A broader range of PVC morphologies was observed in the lateral leads. In lead I, the most common morphologies were QS, monophasic R, and  $R/S < 1$ , with 28, 21, and 19 cases, respectively. Other less common morphologies were also identified.<sup>17,18</sup> In the present study, the morphology of lead I did not significantly aid in predicting ablation failure, in contrast to another study that reported it as a predictor. More research is needed to investigate these observed discrepancies. In contrast to lead I, leads AVL and AVR showed less variation in morphological characteristics. In lead AVL, the QS pattern was predominant, with 59 patients exhibiting this morphology, followed by 13 patients with monophasic R and 6 patients with  $R/S < 1$ . In lead AVR, the majority of patients ( $n = 69$ ) displayed a QS pattern, suggesting that this particular morphology could potentially aid in predicting ablation failure. Other morphologies observed in lead AVR included 5 cases of monophasic R and 6 cases of  $R/S < 1$ . In lead  $V_1$ , the most prevalent pattern was  $R/S < 1$ , observed in 31 cases. This was followed by the QS pattern in 25 cases and the monophasic R pattern in 17 cases. On the other hand, lead  $V_2$  displayed a higher prevalence and percentage of the  $R/S < 1$  pattern than lead  $V_1$ , with 48 cases. Additionally, 11 patients exhibited a monophasic R pattern, and 8 patients had an  $R/S > 1$  pattern. The analysis of transition patterns revealed that 40 cases demonstrated transition in lead  $V_3$ , accounting for half of the patient population. Late transition, which signifies transition

occurring after lead V<sub>3</sub>, was observed in 26 cases. A positive concordance pattern was identified in 11 cases, while only 3 cases exhibited an early transition pattern. These findings suggest that the early transition pattern could potentially serve as a predictor of successful PVC ablation.

The final ECG parameter analyzed in this study was the breakthrough transition pattern, which was observed in 45 patients and demonstrated a significant association with ablation failure. Breakthrough refers to an abrupt loss of the R wave in lead V<sub>2</sub> when compared with leads V<sub>1</sub> and V<sub>3</sub>, indicative of ventricular arrhythmias or PVCs originating from the epicardial surface of the septum, opposite to lead V<sub>2</sub>. The anterior interventricular vein and the posterior interventricular vein, also referred to as the middle cardiac vein, run along the anterior septum, opposite the posterior interventricular septum between the ventricles. Arrhythmias originating from these veins have been shown to predominantly generate contradictory ECG features.<sup>19, 20</sup>

## CONCLUSIONS

The results of this study indicate a higher rate of unsuccessful PVC ablation in males, which is closely associated with the presence of hypertension and smoking. Significantly, the most common location associated with unsuccessful PVC ablation was the LV summit, emphasizing the importance of precise electroanatomic mapping during ablation procedures to ensure optimal targeting and improved outcomes. Furthermore, the breakthrough pattern was frequently observed in PVCs with unsuccessful ablation, suggesting its potential utility as a predictor for ablation success.

## Ethics Approval and Consent to Participate

The protocol of the present study was reviewed and approved by Iran University of

Medical Sciences (IR.IMU.REC.1401.4727). The patients/participants provided their written informed consent to participate in this study.

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## Conflict of Interest

The authors of this research affirm that the study was carried out without any commercial or financial relationships that could potentially be interpreted as a conflict of interest.

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