Medica Hospitalia
Journal of Clinical Medicine
Med Hosp 2026; vol 13 (2) : 146–153

OPEN ACCESS

Original Article

Prolonged P-wave Dispersion Increases Risk of Perioperative Atrial Fibrillation After CABG Surgery

Jiauw, Davinarta Yuwono[1], Pipin Ardhianto[2], Udin Bahrudin[2], Ilham Uddin[2]

[1]Medical Faculty of Diponegoro University Semarang, Indonesia
[2]Department of Cardiology and Vascular Medicine, Medical Faculty of Diponegoro University/ Kariadi Hospital Semarang, Indonesia

p-ISSN: 2301-4369 e-ISSN: 2685-7898
https://doi.org/10.36408/mhjcm.v13i2.1475

Submitted: March 12th, 2026
Accepted: July 28th, 2026

Author's affiliation:
Medical Faculty of Diponegoro University Semarang, Indonesia

Author's correspondence:
Jiauw, Davinarta Yuwono
Prof. Mr. Sunario Street, Tembalang, Semarang, Central Java 50275, Indonesia

E-mail:
davinartayuwono@gmail.com

Abstract

Background : Postoperative Atrial Fibrillation (POAF) is a secondary Atrial Fibrillation caused by cardiac surgical intervention, especially Coronary Artery Bypass Graft (CABG) Surgery. P-wave dispersion (Pdis) represents the difference between the maximum and minimum P-wave durations obtained from a standard 12-lead ECG. P-wave dispersion is considered a non-invasive ECG marker of atrial remodeling and may predict the occurrence of atrial fibrillation.
Aims : This study analyzes the association between P-wave dispersion and Perioperative Atrial Fibrillation after Coronary Artery Bypass Graft Surgery.
Methods : This was an observational, analytic study with a retrospective design. The total number of subjects was 48 patients, divided into the POAF group (n=24) and no POAF group (n=24). Demographic data and preoperative ECG records were obtained from the patient's medical records. The significance of P-wave dispersion was analyzed using independent t-test and logistic regression. The Receiver Operating Characteristic (ROC) test was used to define cut-off values, sensitivity, and specificity of P-wave dispersion.
Results : The total number of subjects in this study was 48 patients, consisting of 43 men and five women. The mean age of the patients was 57.85 ± 5.83 years. The mean P-wave dispersion was higher in patients who experienced POAF (64.97 ± 13.21 vs. 50.55 ± 7.14; p<0.001). P-wave Dispersion was significantly associated with the incidence of POAF (p<0.001; cut-off 55.65 ms; OR 9.00; 95% CI 2.437–33.244).
Conclusion : P-wave Dispersion is significantly associated with Postoperative Atrial Fibrillation. P-wave dispersion value greater than 55.65 ms increases the risk of POAF after CABG by 9-fold.

Keywords : Coronary Artery Bypass Graft, P-wave Dispersion, Postoperative Atrial Fibrillation

INTRODUCTION

Coronary artery disease remains the second leading cause of mortality in Indonesia, contributing to 95.68 deaths per 100,000 Indonesian population or around 14.4% of total deaths in Indonesia.[1] CABG (Coronary Artery Bypass Graft) is typically indicated in the presence of severe obstruction in one or more major coronary arteries, and/or percutaneous coronary intervention (PCI) has failed to adequately relieve the blockage.[2] According to hospital claim data reported by Indonesia's Social Security Agency for health, known as Badan Penyelenggara Jaminan Sosial (BPJS) Kesehatan, a total of 5.967 patients have survived CABG surgery from 2017 to 2022.[1]

Postoperative atrial fibrillation (POAF) was reported in patients undergoing either cardiac or non-cardiac surgery.[2,3] The incidence of POAF in cardiac surgeries is 20–40% compared to 3% in non-cardiac surgeries.[4] Approximately 30% of patients undergoing CABG develop POAF.5 In the vast majority of cases, approximately 90%, POAF manifests during the initial six-day window following a surgical procedure.[6,7] A definitive concept of POAF has not been established, as the criteria used to define POAF differ among authors and within the literature.[4] Generalized definitions of POAF amongst various publications include any POAF that requires treatment, AF lasting greater than 30 seconds in a postoperative patient, new onset of AF post-operation regardless of the duration, or any AF post-operation lasting more than ten minutes.[8] The pathophysiological mechanism underlying POAF is not fully understood, but various etiological factors are recognized as contributing to its development.[4] Preoperative, intraoperative and postoperative factors may contribute to the development of POAF.[4]

P-wave dispersion (Pdis) represents the difference between the maximum and minimum P-wave durations obtained from a standard 12-lead ECG.[9] P-wave duration reflects the time required for complete electrical depolarization of both atria.[23] The local theory suggests that diverse P-wave lengths observed in 12-lead ECG are a result of non-uniform conduction speeds across different regions of the atria.[9] Thus, Pdis is considered to be a non-invasive ECG marker for atrial remodeling and could be used as a predictor of AF.[9,10]

We identified several conflicting findings in the literature regarding mean P-wave dispersion differences between the POAF and the non-POAF group. Research by Jazi MH *et al*. and Achmad C *et al*. demonstrated that the mean P-wave dispersion was significantly higher in the POAF group compared to the no POAF group.[11,24] Conversely, a similar study conducted by Chandy J *et al*. reported no significant differences in Pdis between the two cohorts.[12] In addition, prior studies reported a wide range of mean P-wave dispersion values, indicating significant heterogeneity among study findings. Consequently, the predictive role of P-wave dispersion in stratifying POAF risk after CABG remains uncertain. To the best of our knowledge, this is the first study to establish a specific P-wave dispersion (Pdis) cut-off value for the risk stratification of POAF. Therefore, this study aimed to further investigate differences in Pdis values between the two groups and their association with POAF following CABG surgery.[11–13,24]

METHODS

This research was conducted from November 2023 to September 2024 at RSUP Dr. Kariadi, in Semarang, Central Java, Indonesia. Our study was an analytical observational study with a case-control design without matching. Subject selection used a total sampling method. Every medical record of patients who underwent CABG from October 2022 to October 2023 was screened. POAF was evaluated by Cardiology Arrhythmia Consultant using Holter ECG 96 hours after surgery. The exclusion criteria were patients diagnosed with atrial fibrillation before CABG surgery, arrhythmia in baseline ECG, primary valvular heart disease, congenital heart disease, and incomplete data (missing preoperative ECG or medical record).

The preoperative 12-lead ECG paper was scanned using a *Brother Portable Compact Mobile Scanner DS-640*. P-wave dispersion measurements were performed digitally using ImageJ software by a trained investigator blinded to subject's AF status. The Pdis value was measured by subtracting the longest and shortest P-wave durations from 12-leads ECG with a standard calibration of 25 mm/s. The onset of the P-wave is the first deflection of the isoelectric line defined by the T-P segment, while the offset is defined as the intersection of the tip of the P-wave and its return to the baseline.

Demographic data, including age and sex, were evaluated in two groups; those with AF and those with normal sinus rhythm. Patient's comorbidities evaluated in this study include the presence of diabetes mellitus (DM), congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), previous episode of myocardial infarction (MI), and pericardial effusion. Surgical factors, including aortic cross clamp time (XCT) and cardiopulmonary bypass time (CPB), were also taken into account.

Data analysis was carried out using SPSS version 23.0. The *Shapiro-Wilk* test was used to assess the normality of the data. Either an independent t-test or a *Mann-Whitney* test was used to analyze the numeric variable, whereas the Chi-square test was used to analyze the categorical variable. The intraclass correlation coefficient (ICC) with its 95% confidence interval was used to assses the intrarater reliabiltiy analyses for agreement on absolute agreement with a two-way mixed

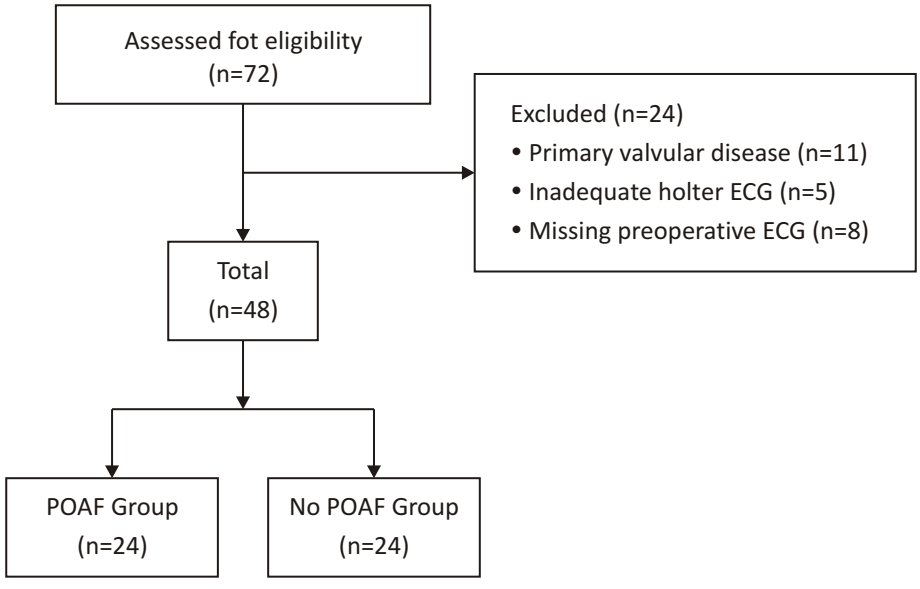

Figure 1. Flowchart of Patient Selection and Grouping

effects model. ICC estimates were calculated on a basis of a total two measurement on 10 participants (the second measurement was performed two weeks after the first measurement). The *Receiver Operating Characteristic* (ROC) test was used to define cut-off values, sensitivity, and specificity of Pdis. Multivariable logistic regression analysis with backward elimination was undertaken to assess the predictors of POAF. Variables with a *p*-value <0.25 in the bivariate analysis were included in the multivariate analysis.

Ethical clearance was approved by the Health Research Ethics Committee, Faculty of Medicine, Universitas Diponegoro, Semarang, with number 169/KEPK/FK-UNDIP/IV/2024.

RESULTS

The total number of subjects was 48, divided equally between the POAF and non-POAF groups. The majority of subjects were men (89.6%). The mean age of the research subjects was 57.85 ± 5.83, and the mean BMI was 25.51 ± 3.76. Patient's comorbid data were DM (39.6%), congestive heart failure (37.5%), COPD (4.3%), CKD (10.4%), and history of MI (43.8%). The mean duration of CPB was 67.94 ± 10.89 minutes, and XCT was 54.90 ± 10.09 minutes. A total of 16 patients (33.3%) developed pericardial effusion after CABG surgery. The baseline characteristics of the subjects was shown in Table 1.

Patients with POAF were one year older than those who remained in sinus rhythm. However, there was no significant difference between the two groups (58.42 ± 5.08 vs 57.29 ± 6.56; *p*=0.51). Regarding gender, there was no significant difference among subjects who developed POAF. As shown in Table 2, subjects who developed AF had a similar body surface area to those with sinus rhythm (26.01 ± 4.27 vs 25.0 ± 3.19; *p*=0.46). Other comorbidities, including DM, CHF, COPD, CKD, history of MI, and pericardial effusion, were similar between the two groups.

No statistically significant differences were observed in surgical variables between the POAF and the non-POAF group. The mean CPB duration was 67.46 ± 10.83 minutes in the POAF group compared to 68.42 ± 11.16 minutes in the no POAF group (*p*=0.764). Likewise, the mean XCT duration was 54.42 ± 10.14 minutes in POAF and 55.38 ± 10.24 minutes in non-POAF (*p*=0.836).

Bivariate analysis with an independent t-test showed that Pdis was significantly higher in patients with POAF (64.97 ± 13.21 vs. 50.55 ± 7,14 ms, *p*<0.001). There were no significant differences in confounding variables between the POAF and the non-POAF groups. A detailed bivariate analysis of confounding variables is presented in Table 2.

Reliability analyses between two measurements indicated good intrarater correlations across P-wave dispersion, as illustrated in Table 3.

Based on ROC analysis, the area under the curve (AUC) was 0.845 (*p*<0.001), indicating very good accuracy. In addition, the cut-off value for P-wave dispersion was 55.65 ms with a sensitivity and specificity of 75%.

Multivariate analysis used logistic regression with P-wave dispersion and left atrial diameter as predictors. In this study, P-wave dispersion was the only variable that influenced the incidence of POAF (OR 9.00, *p*<0.001). These results indicate that patients who have a

TABLE 1
Baseline Characteristics Comparison

Variable	Freq.	%	Mean ± SD	Median (min – max)
Group				
POAF	24	50.0		
No POAF	24	50.0		
Age (years)			57.85 ± 5.83	57 (46 – 71)
Sex				
Men	43	89.6		
Women	5	10.4		
BMI (kg/m^2)			25.51 ± 3.76	24.85 (16.77 – 35.16)
Systolic BP (mmHg)			125.77 ± 20,33	125.5 (86 – 168)
Diastolic BP (mmHg)			72.96 ± 11.88	74.5 (26 – 90)
Diabetes Mellitus				
Yes	19	39.6		
No	29	60.4		
Congestive heart failure				
Yes	18	37.5		
No	30	62.5		
COPD				
Yes	2	4.3		
No	46	95.7		
Chronic kidney disease				
Yes	5	10.4		
No	43	89.6		
History of MI				
Yes	21	43.8		
No	27	56.2		
Pericardial effusion				
Yes	16	33.3		
No	32	66.7		
CPB duration (minutes)			67.94 ± 10.89	65.5 (40–90)
XCT duration (minutes)			54.90 ± 10.09	55 (27–78)
Left atrium diameter				
≤ 40 mm	37	77.1		
> 40 mm	11	22.9		
P-wave dispersion			57.76 ± 12.78	55.65 (34.04–93.09)

BMI: Body Mass Index; BP: Blood Pressure ; COPD: Chronic Obstructive Pulmonary Disease ; MI: Myocardial Infarction ;
CPB: Cardiopulmonary Bypass ; XCT: Aortic Cross-clamp.

TABLE 2
Bivariate Analysis of P-wave Dispersion and Confounding Factor

Variable	Group		*p* value
	POAF	No POAF	
Age (years)	58.42 ± 5.08	57.29 ± 6.56	0.510
Sex			
Men	21 (87.5)	22 (91.7)	0.500
Woman	3 (12.5)	2 (8.3)	
BMI (kg/m^2)	26.01 ± 4.27	25.0 ± 3.19	0.360
Sistolic BP (mmHg)	120.79 ± 19.75	130.75 ± 20.07	0.090
Diastolic BP (mmHg)	70.58 ± 14.20	75.33 ± 8.66	0.239
Diabetes Mellitus			
Yes	5 (20.8)	14 (58.3)	0.376
No	19 (79.2)	10 (41.7)	
Congestive heart failure			
Yes	11 (45.8)	7 (29.2)	0.371
No	13 (54.2)	17 (70.8)	
COPD			
Yes	1 (4.2)	1 (4.2)	1.000
No	23 (95.8)	23 (95.8)	
Chronic kidney disease			
Yes	2 (8.3)	3 (12.5)	0.637
No	22 (91.7)	21 (87.5)	
History of MI			
Yes	10 (41.7)	11 (45.8)	0.771
No	14 (58.3)	13 (54.2)	
Pericardial effusion			
Yes	8 (33.3)	8 (33.3)	1.000
No	16 (66.7)	16 (66.7)	
CPB duration (minutes)	67.46 ± 10.83	68.42 ± 11.16	0.764
XCT duration (minutes)	54.42 ± 10.14	55.38 ± 10.24	0.836
Left atrium diameter			
≤ 40 mm	16 (66.7)	21 (87.5)	0.086
> 40 mm	8 (33.3)	3 (12.5)	
P-wave dispersion (ms)	64.97 ± 13.21	50.55 ± 7.14	<0.001*

*Considered significant (*p* value <0.05). BMI: Body Mass Index; BP: Blood Pressure ; COPD: Chronic Obstructive Pulmonary Disease ; MI: Myocardial Infarction ; CPB: Cardiopulmonary Bypass ; XCT: Aortic Cross-clamp

TABLE 3
Intra-Rater Reliability

	Reliability
P-wave dispersion	0.819 (0.293–0.955)

TABLE 4
P-wave Dispersion Cut-off's Value

	Cut-off	AUC	*p* value	Sensitivity	Specificity
P-wave dispersion	55.65 ms	0.845	<0.001*	75%	75%

*Considered significant (*p* value <0.05)

TABLE 5
Multivariate Analysis Regression Logistic

	Odds Ratio	*p* value	95% CI
P-wave dispersion	9.00	<0.001*	2.437–33.244
Left atrium diameter	3.69	0.085	0.836–16.373

*Considered significant (*p* value <0.05)

preoperative P-wave dispersion higher than 55.65 ms have 9x higher risk of experiencing POAF.

DISCUSSION

The underlying mechanism of POAF has not been completely elucidated.[4] Current evidence suggests that POAF develops through the interaction of a broad spectrum of risk factors, including patient- and surgery-related factors as well as reversible factors. Generally, risk factors of POAF can be classified into three groups based on the perioperative period: preoperative, intraoperative, and postoperative.[14] Among the variables we evaluated, only P-wave dispersion exhibited a significant difference between patients with POAF and those who remained in sinus rhythm (64.97 ± 13.21 vs. 50.55 ± 7.14; p<0.001). These results indicate that the POAF group experienced significantly slower electrical conduction than the non-POAF group. Electrical conduction abnormalities, characterized by prolonged P-wave duration, may be caused by chronic atrial electrical and structural remodeling.[7] While fibrosis protects the myocardial wall, collagen-rich scar tissue can disrupt cardiomyocyte continuity, forcing electrical impulses to traverse longer and slower conduction pathways.[7] Compared with previous studies, we found relatively different Pdis values. Achmad C *et al*. found 53.0 ± 3.8 ms vs. 44.0 ± 2.0 ms, while Khosropanah Sh *et al*. found 79.44 ± 25.0 ms vs. 70.12 ± 22.4 ms.[13,24] We believe this difference may be due to several factors, such as the measurement method used and interobserver variability. We attempted to measure Pdis as accurately as possible to reduce intraobserver variability through digital measurements. Despite these differences, our findings align with previous studies showing that preoperative Pdis values were higher in the POAF group.

In our study, Pdis demonstrated a strong diagnostic performance with an Area Under the Curve (AUC) of 0.845. Using a cut-off value of 55.65 ms, the parameter yielded balanced sensitivity and specificity levels of 75%. These results indicate that Pdis is a reliable predictor for POAF, showing high statistical significance (p<0.001). The same findings were reported by Sahin YB *et al*., who found that AF patients demonstrated significantly elevated Pdis and LAVI.[15] Nevertheless, Sahin YB *et al*. noted that upon multivariate regression, Pdis was the sole parameter to remain independently predictive of AF.[15] In line with our results, Erciyes D *et al*., found that renal transplant recipients with POAF had higher P-wave dispersion than those who maintained a normal sinus rhythm (54.46 ± 1.31 ms vs. 36.28 ± 8.04 ms, p<0.001).[16] Our proposed cut-off value may assist in identifying patients at greater risk of developing POAF, as individuals with a P-wave dispersion greater than

55.65 ms were found to have a ninefold increased risk of POAF. These findings may help clinicians recognize high-risk patients earlier, thereby enabling more intensive monitoring and consideration of preventive strategies.

Confounding preoperative and intraoperative factors that potentially led to the formation of the fibrotic substrate were analyzed in our study. These included aging, Diabetes Mellitus, COPD, CHF, history of MI, LA diameter, CPB and XCT duration.[17,18] However, our study found no differences in confounding factors between the POAF and the non-POAF groups. We initially hypothesized that the POAF group had a higher myocardial fibrosis substrate. As the atria enlarge, fibrosis increases and disrupts normal heart function.[19,23] Thus, a longer P-wave on an ECG is considered an indicator of a larger left atrium. We evaluated left atrial (LA) enlargement using LA diameter to assess pathological changes that could be structurally visualized.[25] However, in this study, LA diameter did not differ significantly between the two groups (p=0.086). Despite the POAF group exhibiting a higher LA diameter compared to the non-POAF group, the disparity was statistically insignificant (p=0.086). Thus, the study failed to support our hypothesis regarding atrial anatomical changes in CABG patients. We concluded that this heterogeneity in conduction was caused by pre-existing conditions, namely microfibrosis, which was not yet apparent in LA diameter parameters.

Eventually, patients experiencing POAF exhibit a more pronounced process of atrial structural remodeling. This progression leads to a disruption in atrial depolarization, primarily driven by conduction blockages within the fibrotic tissue.[19] Based on the higher P-wave dispersion value in this research, patients who developed POAF have a greater substrate component, which elevates the risk of POAF after CABG. However, substrate-related components are not the sole determinants of POAF.[20] Various intraoperative and postoperative factors may also contribute to its development.[21] In this context, a fibrotic atrial substrate may represent a pre-existing condition that predisposes patients to POAF, whereas perioperative factors likely act as triggering mechanisms for the occurrence of POAF in this study population.[22] We believe this study has important clinical relevance and practical applicability, as a 12-lead ECG is routinely obtained during preoperative evaluation and the digital method for P-wave dispersion measurement is relatively simple to perform.

LIMITATIONS

We had several limitations in this study. Firstly, this study was a small, retrospective, and single-center study. Secondly, the P-wave dispersion was measured at a paper speed of 25 mm/s, whereas it is ideally measured at a 50 mm/s for greater precision. Our study focused on the preoperative period, the findings may be limited by unaccounted preoperative and postoperative variables that could have influenced the study's outcome. Nevertheless, several improvements may be considered in future clinical applications and research. These include measuring Pdis at 50 mm/s and analyzing other perioperative variables such as inflammatory markers, medication use, and electrolyte levels.

CONCLUSION

Higher P-wave dispersion significantly associated with the incidence of POAF after CABG. P-wave dispersion value greater than 55,65 ms increases the risk of POAF after CABG by 9 times. Utilizing preoperative P-wave dispersion for risk stratification facilitates the preoperative identification of high-risk candidates slated for CABG.

ACKNOWLEDGES

The authors would like to express their gratitude to Aboesina Sidiek, MD, for his assistance in clinical data acquisition. We also extend our appreciation to the administrative and medical records staff at Dr. Kariadi General Hospital, Semarang, for their cooperation.

CONFLICT OF INTEREST

The authors have no conflicts of interest that could affect the results or interpretation in this report.

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