

# The true nature of P wave dispersion

Jacek Marcin Zawadzki<sup>1,A,C–F</sup>, Katarzyna Zimmer<sup>2,A–C,E,F</sup>, Wojciech Przywara<sup>3,A–C,E,F</sup>,  
Dorota Zysko<sup>4,C,E,F</sup>, Jadwiga Radziejewska<sup>1,B,C,F</sup>, Agnieszka Sławuta<sup>5,B,C,E,F</sup>, Jacek Gajek<sup>6,A–F</sup>

<sup>1</sup> Department of Cardiology, Klodzko County Hospital, Poland

<sup>2</sup> Clinic and Department of Ophthalmology, Wrocław Medical University Hospital, Poland

<sup>3</sup> Department of Dermatology, Regional Specialist Hospital in Wrocław, Poland

<sup>4</sup> Department of Emergency Medicine, Wrocław Medical University, Poland

<sup>5</sup> Department of Internal and Occupational Diseases, Hypertension and Clinical Oncology Wrocław Medical University, Poland

<sup>6</sup> Department of Emergency Medical Service, Wrocław Medical University, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Advances in Clinical and Experimental Medicine, ISSN 1899–5276 (print), ISSN 2451–2680 (online)

*Adv Clin Exp Med.* 2020;29(12):1443–1447

## Address for correspondence

Jacek Zawadzki

E-mail: jacekzawadzki@gmail.com

## Funding sources

None declared

## Conflict of interest

None declared

Received on May 25, 2020

Reviewed on June 1, 2020

Accepted on October 8, 2020

## Abstract

**Background.** The electrophysiological activity of the heart is recorded and presented in form of electrocardiography (ECG). In 1998, the concept of P wave dispersion as the risk factor for atrial fibrillation (AF) recurrence was introduced. It was calculated as the difference between the longest and the shortest P wave.

**Objectives.** To prove that the P wave dispersion is an artifact of low accuracy in P wave measurement.

**Material and methods.** The study included 104 patients (48 women, 56 men), aged  $63 \pm 14$  years, undergoing various electrophysiological procedures. The P wave was measured twice – firstly at the paper speed of 50 mm/s, enhancement  $\times 8$  (standard – imprecise), and secondly at 200 mm/s,  $\times 64$ –256 (precise).

**Results.** The imprecise measurement method resulted in different duration of all P wave parameters in comparison with precise measurement. The longest P wave duration (Pmax) measured imprecisely was  $105.1 \pm 22.1$ , the Pmax measured precisely was  $134.0 \pm 21.3$  ( $p < 0.001$ ). The P dispersion measured imprecisely was  $44.1 \pm 16.8$  and the P dispersion measured precisely was  $2.8 \pm 3.4$  ( $p < 0.0001$ ). The correlation between imprecise Pmax and imprecise Pmin was  $r = 0.664$  ( $p < 0.05$ ). The correlation between imprecise Pmax and imprecise P wave dispersion was  $r = 0.612$  ( $p < 0.05$ ). The correlation between precise Pmax and Pmin was almost 1.0 ( $r = 0.987$ ,  $p < 0.05$ ).

**Conclusions.** The P wave dispersion does not exist. The measurements of the P wave have to be precise to assure the highest scientific and medical sincerity. The highest clinical value is related to the P wave duration.

**Key words:** P wave dispersion, P wave duration, total atrial activation time

## Cite as

Zawadzki JM, Zimmer K, Przywara W, et al.

The true nature of P wave dispersion. *Adv Clin Exp Med.*

2020;29(12):1443–1447. doi:10.17219/acem/128232

## DOI

10.17219/acem/128232

## Copyright

Copyright by Author(s)

This is an article distributed under the terms of the

Creative Commons Attribution 3.0 Unported (CC BY 3.0)

(<https://creativecommons.org/licenses/by/3.0/>)

## Introduction

The electrophysiological activity of the working myocardium is recorded by the system of simultaneous leads of the electrocardiograph and presented in the form of electrocardiography (ECG).<sup>1</sup> The morphology of ECG recording in a specific lead is the result of the direction of the depolarization wave propagation and the range of spatial registration of the given lead.<sup>2</sup> The recording is performed simultaneously in all leads, i.e., the given phenomenon is recorded simultaneously by all leads of the electrocardiogram.<sup>3</sup> In the case of a perpendicular activation vector in a bipolar lead and a parallel vector in the case of a unipolar lead, the isoelectric line is recorded by given lead.<sup>4</sup>

In 1998, Dilaveris et al. introduced the concept of P wave dispersion as ‘a marker of the nonuniform anisotropic inhomogeneous atrial conduction’ – cited from the original work – and the risk factor for atrial fibrillation (AF) recurrence.<sup>5</sup> This P wave dispersion was determined as the difference between the longest and the shortest P wave duration (Pmax and Pmin), measured in 2 different ECG leads. The measurement methodology included simultaneously recording all 12 leads at the paper speed of 50 mm/s and the enhancement of 1 mV/cm as well as using a magnifying lens to increase measurement precision. In a group of 60 patients aged  $59.0 \pm 12.0$  years with diagnosed idiopathic paroxysmal AF, the mentioned dispersion was  $49 \pm 15$  ms (Pmax) and  $28 \pm 7$  ms (Pmin) in the group of 40 healthy people, which was statistically significant. It should be emphasized that the compared groups were well matched according to the sociodemographic parameters, left atrial size, atrioventricular conduction time, and left ventricular ejection fraction (LVEF). In addition to the value of dispersion measured this way, the study groups also differed in the duration of the P wave ( $123 \pm 16$  ms compared to  $101 \pm 10$  ms,  $p < 0.0001$ ). Further statistical analysis showed that the risk of recurrent AF in patients was more related to the dispersion parameter exceeding 40 ms than the duration of the P wave above 110 ms.<sup>5</sup> In the following years, many researchers reproduced the original results, using more or less the same flawed methodology in various groups of patients and reaching similar conclusions.<sup>6–8</sup>

The research hypothesis of our study is to prove the non-existence of the P wave dispersion parameter, i.e., the defined parameter is an artifact of no accuracy in measuring the P wave (incorrect measurement methodology). The aim of our study was to assess the P wave parameters in the patient group undergoing different electrophysiological procedures.

## Material and methods

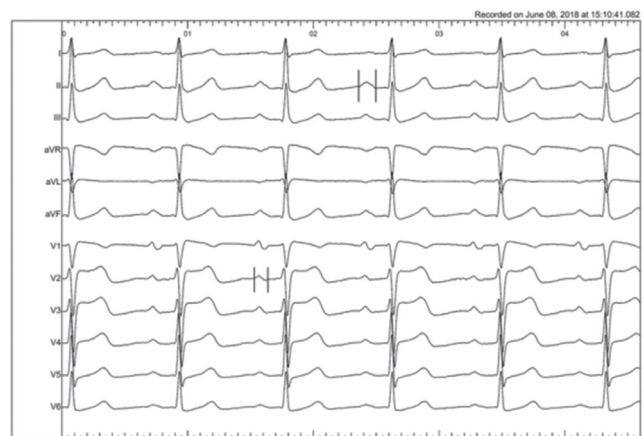
The study included 104 non-selected patients (48 women, 56 men), aged  $63 \pm 14$  years (range: 21–89 years), undergoing various electrophysiological procedures using

LabSystemTM Pro EP Recording System (Boston Scientific, Boston, USA), (electrophysiological studies; AV-nodal reentrant tachycardia (AVNRT), atrioventricular reentrant tachycardia (AVRT), atrial flutter (AFL), right ventricular outflow tract (RVOT) arrhythmia ablations). The only inclusion criterion was the presence of sinus rhythm and the quality of the ECG tracings, which allowed us to measure the sinus P wave duration.

The P wave duration was measured in all leads twice: firstly time at the paper speed of 50 mm/s, enhancement  $\times 8$  (basic measurement), and secondly at the paper speed of 200 mm/s, enhancement  $\times 64$ – $256$  (Fig. 1). The P wave dispersion was calculated as the difference between Pmax and Pmin in different leads for each measurements setting. The P wave measurements for every tracing were repeated 5 times for accuracy by 2 independent researches, who were unaware of each other’s results and who were blinded to clinical data. The final value presented for each patient was their mean.

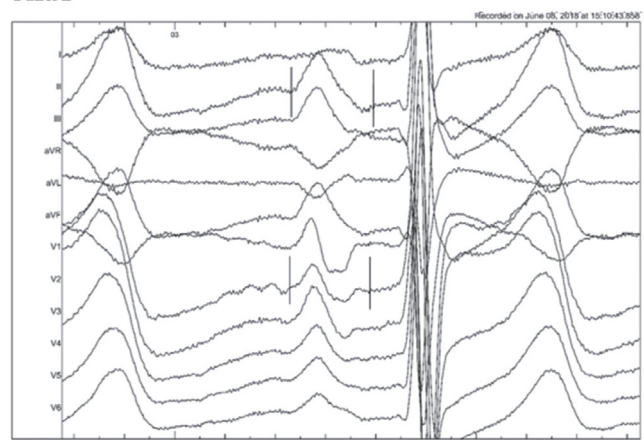
The study was approved by the local Bioethical Committee at Wroclaw Medical University, Poland.

Panel A



Lead II: 140 ms; Lead V2: 99 ms; Speed: 50 mm/s; Enhancement: 8x

Panel B



Lead II: 172 ms; Lead V2: 166 ms; Speed: 200 mm/s; Enhancement: 128x

Fig. 1. The methodology of P wave duration measurements and P wave dispersion calculations in different settings

A – imprecise measurement indicated the Pmax in lead II and Pmin in lead V2; B – the same was repeated in precise way in the same leads.

## Statistical analysis

The continuous variables are presented as the means and standard deviations (SD) or medians and interquartile ranges (IQRs). The comparisons were performed with the parametrical Students-t test or non-parametrical Wilcoxon paired test for dependent variables. The correlations between the studied parameters were performed using Pearson’s correlations coefficient or Spearman’s rank correlation according to the statistical properties of the data. The p-values less than 0.05 were considered to be statistically significant.

## Results

The results of the P wave parameters measurements using the standard method (basic measurements) and the precise method and their derivatives are presented in Table 1.

The use of the imprecise measurement method (basic measurement) resulted in significantly different duration of all P wave parameters taken, in comparison with precise measurement. What is more important, the difference between Δ Pmax and Δ Pmin indicated a much higher value for the latter parameter. The correlation between imprecise Pmax and imprecise Pmin is presented in Fig. 2. This presented relationship indicated a high correlation coefficient, amounting to 0.7. The correlation between imprecise Pmax and imprecise P wave dispersion is depicted in Fig. 3.

It was indicated that the imprecise P wave dispersion value correlated highly significantly with Pmax measured in a similar way. The correlation between precise Pmax and precise Pmin is shown in Fig. 4.

In contrast with the imprecise measurement method, Pmax and Pmin measured accurately were almost identical.

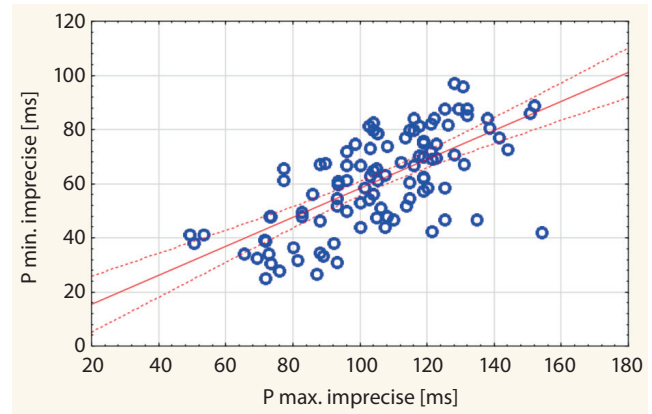


Fig. 2. The correlation between imprecise Pmax and imprecise Pmin (r = 0.664, p < 0.05)

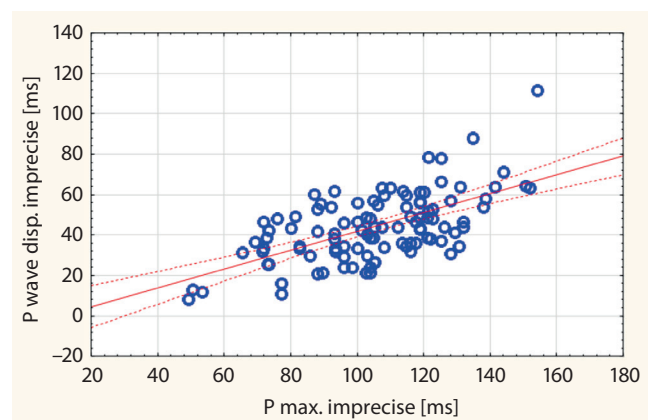


Fig. 3. The correlation between imprecise Pmax and imprecise P wave dispersion (r = 0.612, p < 0.05)

This resulted in correlation coefficient approaching 1.0. Figure 5 presents the contrast between the imprecise and precise Pmax measurements.

Table 1. Basic statistics of the P wave parameters

Parameters [ms]	Basic statistics		
	M ±SD	Me [Q1, Q3]	Min–Max
Pmax			
Imprecise (n = 104)	105.1 ±22.1*	105.3 [90.7; 120.5]	49.3–154.0
Precise (n = 104)	134.0 ±21.3*	130.5 [120.8; 149.3]	54.3–199.0
Pmin			
Imprecise (n = 104)	61.0 ±17.8#	61.7 [47.3; 75]	25.3–97.3
Precise (n = 104)	131.2 ±21.2#	128.5 [118.0; 147.2]	54.3–187.3
P wave dispersion			
Imprecise (n = 104)	44.1 ±16.8&	43.3 [33.3; 55.3]	8.0–112.0
Precise (n = 104)	2.8 ±3.4&	1.4 [0.0; 5.4]	0.0–11.7
Pmax difference (Δ)	29.0 ±26.3®	22.3 [9.8; 42.6]	–6.7–108.3
Pmin difference (Δ)	70.2 ±28.0®	67.4 [49.8; 88.4]	13.0–147.0

\*p < 0.001; #p < 0.001; &p < 0.0001; ®p < 0.001; M – mean; SD – standard deviation; Me – median; Q1 – lower quartile; Q3 – upper quartile; Min–Max – minimal–maximal range.

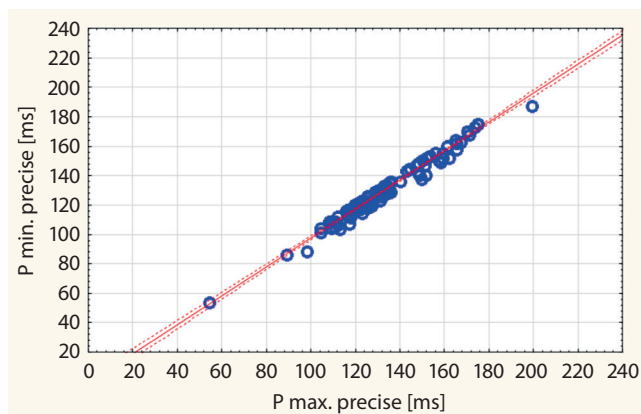


Fig. 4. The correlation between precise Pmax and precise Pmin ( $r = 0.987$ ,  $p < 0.05$ )

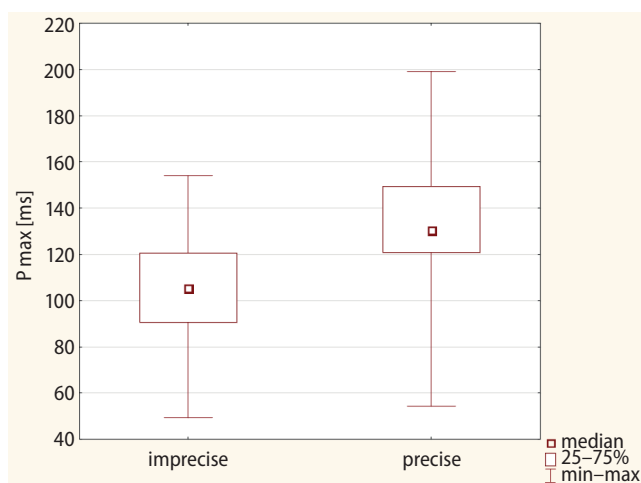


Fig. 5. The contrast between the imprecise and precise Pmax measurements ( $p < 0.001$ )

## Discussion

One of the main principles of ECG is the simultaneous recording of an electrical signal in each lead. Therefore, if an event started in one lead, it continues in all others simultaneously. Similarly, if it is still present in any lead, it cannot be assumed that in the others it has already ended. The ECG signal – lead direction dependence mentioned in the introduction in the individual types of leads – results in the fact that some of them do not register a signal (isoelectric line) when the electric vector moves in a specific direction relative to the lead. In reality, however, we do not deal with 0/1 situations understood in this way and the isoelectric line in a given lead, in the face of an ongoing event in other leads, never occurs. At most, the voltage of the recorded signal in a given situation is beyond our perception.

The main result of our study, performed in an unselected group of patients undergoing electrophysiological procedure, disproves the existence of the so-called P wave dispersion. The use of an accurate method of the measurement

of the P wave duration eliminates the difference between the so-called Pmax and Pmin, i.e., the dispersion tends to 0. In fact, the difference of 0 ms was in the group of the studied patients in 46 out of 104 patients, up to 5 ms in 31 out of 104 patients, up to 10 ms in 24 out of 104 patients, and more than 10 ms in 3 patients. What is more, the high dispersion relationship of the P wave with Pmax, both measured using an imprecise method, clearly shows that the so-called dispersion is a derivative of the real length of the P wave and any of its incorrect (not precisely measured) minimum lengths. In addition, the correlation we have shown of Pmax and Pmin measured precisely, with a correlation coefficient tending to unity, confirms our conclusion.

It is not without reason that the precision of the P wave measurement, or rather the lack thereof, has been the subject of numerous studies over the past 2 decades, following the publication of the original publication on the P wave dispersion parameter.<sup>9,10</sup> The authors were aware of the key importance of measurement accuracy and precision for proper clinical judgement. Even the author of the concept of the dispersion P wave pointed to such need relatively recently.<sup>11</sup> However, these voices always assumed the presence of the parameter itself and the methodology used (e.g., paper shifts 50 mm/s and gain 2 cm/1 mV, with the use of magnifying glasses) was far from perfect.<sup>12,13</sup> In addition, no one indicated the key incompatibility of dispersion with the ECG principles mentioned previously.

Already in 2015, we pointed to the aforementioned problem, using the results on slightly more modest patient material. Based on similar results, we pointed out that the concept of P wave dispersion is based on incorrect methodology and in reality does not exist.<sup>14</sup> Although this publication did not go unnoticed, in the meantime, numerous papers have been published that still describe the phenomenon of P wave dispersion,<sup>15–17</sup> and an interesting interpretation of our study has appeared.<sup>6</sup> Chávez-González and Donoiu, while citing our work, commented it like this: “Despite this, we continue to believe there is sufficient proof supporting the PWD (P wave dispersion) importance in the clinical practice and continuation of research.” The word ‘believe’ is crucial in this context.

In the perspective of our results, there is a need to reassess the initial brilliant idea of the relation between the P wave parameters and the risk of atrial arrhythmia, in particular AF. The already mentioned inaccuracy issues related to the P wave duration measurements are obviously caused by the small amplitude of P waves in some ECG leads. Low amplitude P wave signal is characteristic for advanced atrial muscle disease, which obviously will result in time in AF. There is a vast variety of scientific papers supporting this issue.<sup>18–20</sup> Moreover, the interatrial conduction abnormalities introduced so successfully by Bayés de Luna et al. and other researchers could be also the causes of changes in amplitude and morphology of the P wave.<sup>21,22</sup> In our opinion, the initial results



indicating the more relevant relation of AF with P wave dispersion than P duration is clearly the result of the discussed measurements inaccuracy.

In summary, in light of our results, we conclude that the so-called P wave dispersion is a measurement artefact, related to wrong methodology. The increase in measurement precision makes it simply disappear. Its clinical utility can be explained by its dependence on P wave duration, which reflects the left atrial muscle structural and functional disorders. The proper P wave duration parameter should be the ‘total atrial activation time’ already proposed by us, calculated in the simultaneously recorded 12-lead ECG, from the beginning of the earliest recorded P wave deflection, until the end of the latest P wave deflection recorded in any lead.<sup>14</sup> This approach was recently supported by Bayés de Luna et al., explicitly advising that the P wave should be measured from its earliest beginning in any lead to the latest end in any lead.<sup>23</sup> Most probably the 21<sup>st</sup> century will require appropriate methodology and change of approach.

## Study limitations

A serious limitation of our study is its single-center nature and relatively small study group. In addition, this is not a prospective study showing the relationship between ECG parameter and clinical prognosis. The influence of the human factor and the screen resolution of the monitors on the possibilities of limiting its impact on the obtained measurement results have not been discussed, and it should be emphasized that even with the precise measurement methodology, the differences in P wave duration were not 0 ms in all patients. Additionally, ECG tracing artifacts may influence even very precise measurements.

## Conclusions

1. The P wave dispersion does not exist.
2. The measurements of the P wave and considerations of its doubtless clinical usefulness have to be precise to assure the highest scientific and medical sincerity.
3. The highest clinical value is related to the properly measured P wave duration.

## ORCID iDs

Jacek Marcin Zawadzki  <https://orcid.org/0000-0003-4000-4164>  
 Katarzyna Zimmer  <https://orcid.org/0000-0003-2300-8585>  
 Wojciech Przywara  <https://orcid.org/0000-0002-1245-4785>  
 Dorota Zyśko  <https://orcid.org/0000-0001-9190-0052>  
 Jadwiga Radziejewska  <https://orcid.org/0000-0001-9153-9754>  
 Agnieszka Sławuta  <https://orcid.org/0000-0001-5671-9864>  
 Jacek Gajek  <https://orcid.org/0000-0002-0038-1750>

## References

1. Becker ED. Fundamentals of electrocardiography interpretation. *Anesth Ed.* 2006;53(2):53–64.
2. Murthy ISN, Prasad GSSD. Analysis of ECG from pole-zero models. *IEEE Trans Biomed Eng.* 1992;39(7):741–751.
3. Bayés de Luna A. *Basic Electrocardiography: Normal and Abnormal ECG Patterns.* Hoboken, NJ: Blackwell Publishing; 2008. ISBN-13: 978-1405175708.
4. Grant RP. Spatial vector electrocardiography: A method for calculating the spatial electrical vectors of the heart from conventional leads. *Circulation.* 1950;2(5):676–695.
5. Dilaveris PE, Gialafos EJ, Sideris SK, et al. Simple electrocardiographic markers for the prediction of paroxysmal idiopathic atrial fibrillation. *Am Heart J.* 1998;135(5 Pt 1):733–738.
6. Chávez-González E, Donoio I. Utility of P-wave dispersion in the prediction of atrial fibrillation. *Curr Health Sci J.* 2017;43(1):5–11.
7. Aytémir K, Ozer N, Atalar E, et al. P wave dispersion on 12-lead electrocardiography in patients with paroxysmal atrial fibrillation. *Pacing Clin Electrophysiol.* 2000;23(7):1109–1112.
8. Gunduz H, Binak E, Arinc H, et al. The relationship between P wave dispersion and diastolic dysfunction. *Tex Heart Inst J.* 2005;32(2):163–167.
9. Darbar D, Jahangir A, Hammill SC, Gersh BJ. P wave signal-averaged electrocardiography to identify risk for atrial fibrillation. *Pacing Clin Electrophysiol.* 2002;25(10):1447–1453.
10. Nakatani Y, Sakamoto T, Yamaguchi Y, Tsujino Y, Kataoka N, Kinugawa K. Coefficient of variation of P-wave duration measured using an automated measurement system predicts recurrence of atrial fibrillation. *J Electrocardiol.* 2019;53:79–84.
11. Dilaveris P, Tousoulis D. P-wave dispersion measurement: Methodological considerations. *Indian Pacing Electrophysiol J.* 2017;17(3):89.
12. Dilaveris P, Stefanadis C. P-wave dispersion and atrial fibrillation risk: Methodological considerations. *Am J Cardiol.* 2011;107(9):1405.
13. Dilaveris PE, Gialafos JE. P-wave duration and dispersion analysis: Methodological considerations. *Circulation.* 2001;103(21):E111-1.
14. Zimmer K, Przywara W, Zyśko D, Sławuta A, Gajek J. The nature of P-wave dispersion: A clinically useful parameter that does not exist. *Int J Cardiol.* 2016;212:59–60.
15. Yolbaş S, Yıldırım A, Düzenci D, Karakaya B, Necati Dağlı M, Serdar Koca S. QT dispersion and P wave dispersion in patients with fibromyalgia. *Eur J Rheumatol.* 2016;3(4):165–168.
16. Pérez-Riera AR, de Abreu LC, Barbosa-Barros R, Grindler J, Fernandes-Cardoso A, Baranchuk A. P-wave dispersion: An update. *Indian Pacing Electrophysiol J.* 2016;16(4):126–133.
17. Demirci S, Arslan A, Yürekli VA, Kutluhan S, Rifat Koyuncuoğlu H, Demirci S. P-wave dispersion in patients with Guillain-Barré syndrome. *Acta Neurol Belg.* 2017;117:289–293.
18. Park JK, Park J, Uhm JS, Joung B, Lee MH, Pak HN. Low P-wave amplitude (<0.1 mV) in lead I is associated with displaced inter-atrial conduction and clinical recurrence of paroxysmal atrial fibrillation after radiofrequency catheter ablation. *Europace.* 2016;18(3):384–391.
19. Schreiber T, Kähler N, Tscholl V, et al. Correlation of P-wave properties with the size of left atrial low voltage areas in patients with atrial fibrillation. *J Electrocardiol.* 2019;56:38–42.
20. Ooie T, Wakisaka O, Hujita T, et al. A specific combination of P wave duration and morphology accurately predicts the presence of left atrial low voltage area in patients with atrial fibrillation. *J Electrocardiol.* 2019;2019:S0022-0736(19)30549-7.
21. Bayés de Luna A, Fort de Ribot R, Trilla E, et al. Electrocardiographic and vectorcardiographic study of interatrial conduction disturbances with left atrial retrograde activation. *J Electrocardiol.* 1985;18(1):1–13.
22. Holmqvist F, Platonov PG, Carlson J, Zareba W, Moss AJ; MADIT II Investigators. Altered interatrial conduction detected in MADIT II patients bound to develop atrial fibrillation. *Ann Noninvasive Electrocardiol.* 2009;1(3):4:268–275.
23. Bayés de Luna A, Baranchuk A, Escobar Robledo AL, Massó van Roessel A, Martínez-Sellés M. Diagnosis of interatrial block. *J Geriatr Cardiol.* 2017;14(3):161–165.