Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

P-Wave Duration and Dispersion in Patients with Mitral Stenosis

Wenxia Fu
Shanghai Chest Hospital: Shanghai Jiao Tong University Affiliated Chest Hospital
Jiawei Le
Shanghai Chest Hospital: Shanghai Jiao Tong University Affiliated Chest Hospital
Xijin Wei
Shandong University of Traditional Chinese Medicine Affiliated Hospital
lixiu chen
Shanghai Chest Hospital: Shanghai Jiao Tong University Affiliated Chest Hospital
Wenzhao Li
Shanghai Chest Hospital: Shanghai Jiao Tong University Affiliated Chest Hospital
Ruogu Li (liruogu1234@163.com)
Shanghai Chest Hospital: Shanghai Jiao Tong University Affiliated Chest Hospital
https://orcid.org/0000-0002-4456-919X

Research article

Keywords: mitral stenosis, P-wave dispersion, P-wave duration, maximum P-wave electrocardiogram

Posted Date: February 10th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-200176/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Abstract

Background: Mitral stenosis (MS) is related to prolonged inter- and intra-atrial electromechanical delays and increased P-wave dispersion. The objective of the current study was to investigate the correlation between the P-wave duration, P-wave dispersion (PWD), mitral stenosis (MS) and to explore the cut-off values for predicting the MS in the patients.

Methods: We enrolled 62 patients with MS and sinus rhythm as test group, and 62 healthy subjects matched in age- and sex- were selected as control group. We conducted the 12-lead electrocardiogram and echocardiography for all the subjects. The maximum and the minimum P-wave duration and PWD were calculated. Univariate and multivariate logistic regression analyses were performed to demonstrate the correlation between P-wave duration and PWD and MS. The receiver operating characteristic (ROC) curve was drawn to detect the threshold of P-wave duration and PWD for predicting the MS.

Results: There were significant differences in the left atrial diameter (45.00±5.78 *vs.* 32.31±4.24 cm^2), pulmonary artery pressure (46.68±17.29 *vs.* 32.64±2.86 mm Hg), left ventricular end-diastolic diameter (47.57±4.80 *vs.* 45.58±5.04 cm), ejection fraction (63.10±3.05 *vs.* 65.13±2.56%), aortic root inside diameter (29.60±3.50 *vs.* 31.58±3.58) and pulmonary trunk (24.17±2.78 *vs.* 22.23±1.77) values between the test group and the control group. Besides, the test subjects had significantly longer maximum P-wave duration (123.42±12.33 *vs.* 108.18±9.07) and larger P-wave dispersion (47.24±13.61 *vs.* 28.94±9.19). In the multivariate analysis, maximum P-wave duration (OR:1.221, 95% CI:1.126-1.324) and P-wave dispersion (OR:1.164, 95% CI:1.094-1.238) were correlated with the occurrence of MS. The optimal threshold for the maximum P-wave duration and PWD were 119.50ms, and 42.50ms, respectively, and the areas under the curve were 0.859 and 0.865, respectively.

Conclusions: A longer P-wave duration and a higher PWD are correlated with the increased risk of MS progression.

Background

The rheumatic mitral stenosis (MS) is a highly prevalent, clinically acquired, and progressive valvular cardiac disorder. It commonly occurs in developing countries burdened with the weak economy, which results in a notable rise in morbidity and mortality rate [1]. The most common cause of aberrant atrial conduction is abnormal mitral valve structure or dysfunction, which is related to the increased risk of atrial fibrillation (AF). Protraction of conduction time in atrium and atrium and uneven sinus impulse transmission are the electrophysiological features associated with the AF [2, 3]. Electrocardiographic features have long been evaluated with the help of electrocardiogram (ECG) and transesophageal ultrasound. However, the application of ECG characteristics for helping the diagnosis of MS is rarely studied.

P-wave reflects the electrical activity of the atria, and the features of P-wave, especially P-wave duration, can be used as markers of changes in atrial conduction P-wave dispersion (PWD) refers to the

differences leads of ECG. Previous study showed a novel electrocardiographic indication for heterogeneous and intermittent dissemination of sinus impulses from the ECG[4]. Furthermore, escalated PWD on surface ECG signifies the increased risk of AF and left atrial volume[5]. The relationship between the MS and P-wave indices remains unclear and demands further investigation.

The objectives of the current study were: (1) to compare the electromechanical prolongation in the atrium of MS patients and healthy individuals; (2) to investigate the association between the electromechanical prolongation in atrium and the PWD in MS patients and healthy individuals; (3) to establish the optimal threshold to test the Chinese subjects with MS.

2. Methods

2.1 Study subjects

We diagnosed 598 consecutive patients with mitral stenosis (MS) by echocardiography at the Shanghai Chest Hospital Affiliated to Shanghai Jiaotong University, from May 2016 to December 2019. The exclusion criteria were primary or secondary hypertension, coronary disease, type 2 diabetes, permanent or paroxysmal AF, severe aortic or mitral regurgitation, aortic stenosis, valvular intervention, thyroid dysfunction, respiratory diseases, bundle branch block, intraventricular conduction dysfunction, ventricular preexcitation, prior pacemaker implantation or irregular electrolytes. The sinus rhythm for each test subject was confirmed by testing on a 12-lead electrocardiogram (ECG) before the start of the study. Besides, an echocardiographic evaluation was also conducted for each test subject. Our exclusion criteria resulted in a final cohort of 62 patients (22 mild, 22 moderate, and 18 severe cases of MS). The healthy control group included in this study contained 62 individuals from our hospital without a history of cardiac diseases or the presence of cardiovascular hazard factors. The ethics committee of the Shanghai Chest Hospital Affiliated to Shanghai Jiaotong University approved our study.

2.2 Echocardiography

A couple of trained physicians, blinded to patient's characteristics, performed all the echocardiographic examinations by using an ultrasound echocardiography (Vivid E95, General Electric, USA) with a 3-MHz sensor. After 15 minutes, participants were assessed by ECG in the left recumbent position. The LA diameter and left ventricular end-systolic and end end-diastolic diameters were calculated. Additionally, the mitral valve area (MVA) was estimated by employing a mean pressure half-life and planimetric approach. MVA less than or equal to 1 cm^2 was marked as severe, 1 cm^2 < MVA ≤ 1.5 cm^2 was marked as moderate, and 1.5 cm^2 MVA < 2 cm^2 was marked as mild stenosis.

2.3 Twelve- Lead Ecg

We used a 12-lead ECG with a speed of 25 mm/s, and a voltage of 10 mm/mv to document the information in the test subjects under the supine position. In order to acquire accurate data, we calculated ECGs manually by using a magnifying function by the Nalong system. Before recording the ECG, the test subjects were rested for 15 min and confirmed for the presence of sinus rhythm by ECG. Two trained observers blindly completed the gauge of the P-wave duration. It was measured in milliseconds from all the 12 leads. The starting point of the P-wave was reported as the point where the original deflection of the P-wave crossed the equipotential line, and the endpoint of P-wave was reported as the outlet where the eventual deflection of P-wave crossed the equipotential line. The P-maximum was defined as the longest duration, and the P-minimum was described as the shortest duration among the 12 leads. The P-wave dispersion (PWD) was described as the difference between the maximum P-wave duration and the minimum P-wave duration. Additionally, in this study, we also included test subjects with P waves in nine or more leads that could be precisely measured (6).

2.4 Statistical Methods

The continuous variables are presented as the mean ± standard deviation (SD), and categorical variables are presented as number and frequencies (%). The Student's *t*-test, Wilcoxon rank-sum test, Pearson Chi-square test, and Fisher exact test were employed for the comparison of the continuous and the categorical variables. Univariate and multivariate logistic regression analyses were performed to demonstrate the correlation between P-wave duration and PWD and MS. The receiver operating characteristic (ROC) curve was drawn to detect the threshold of P-wave duration and PWD for predicting the MS. P-value < 0.05 was represented as statistically significant. Data were analyzed using the SPSS Statistics software (version 22.0).

3. Results

3.1 Baseline characteristics

The baseline descriptions of the test subjects and the control individuals are indicated in Table 1. 62 patients (15 males; mean age 55.63 ± 12.53) and an age-sex matched 55-year-old healthy control subject was enrolled in this study. Among the total test subjects included in this study, 22 had mild MS, 22 had moderate MS and 18 had severe MS. Both the test and the control groups were age, height, weight, BMI, heart rate, SBP, and DBP matched.

Table 1
Demographic and Clinical characteristics of patients with mitral stenosis and control subjects

	Control group (n = 62)	Mitral stenosis group (n = 62)	*P* value
Age (years)	58.39 ± 10.48	55.63 ± 12.53	0.19
Height (m)	1.63 ± 0.07	1.61 ± 0.07	0.14
Weight (Kg)	61.07 ± 8.48	58.57 ± 7.45	0.12
BMI (kg/m^2)	22.30 ± 2.43	22.77 ± 1.95	0.33
Male (n, %)	22(35.48)	15(24.19)	0.17
Heart rate (beat/min)	79.65 ± 6.07	77.74 ± 8.18	0.14
SBP (mmHg)	122.98 ± 10.14	119.44 ± 11.29	0.07
DBP (mmHg)	74.52 ± 5.70	73.76 ± 6.91	0.51
Pulse pressure(mmHg)	48.47 ± 10.32	45.68 ± 10.68	0.14
Note: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure			

3.2 Routine ultrasound echocardiography and ECG factors of the MS and the control group

We have demonstrated the baseline ultrasound echocardiography and ECG descriptions of the test and the control group in **Table 2**. In the test group, the mean mitral valve was 1.44 ± 0.47 cm^2. As compared to the control group, no notable difference was observed in the left atrial diameter (45.00 ± 5.78 *vs.* 32.31 ± 4.24 cm^2, $P < 0.01$), pulmonary artery pressure (46.68 ± 17.29 *vs.* 32.64 ± 2.86 mm Hg, $P < 0.01$), left ventricular end-diastolic diameter (LVEDd) (47.57 ± 4.80 *vs.* 45.58 ± 5.04 cm, $P = 0.03$), EF (63.10 ± 3.05 *vs.* 65.13 ± 2.56%, $P < 0.01$), aortic root inside diameter (29.60 ± 3.50 *vs.* 31.58 ± 3.58 cm, $P < 0.01$) and pulmonary trunk (24.17 ± 2.78 *vs.* 22.23 ± 1.77 cm, $P < 0.01$) of the test group. No statistically significant difference was observed in the interventricular septum diastolic diameter (IVSDd) (9.37 ± 1.40 *vs.* 9.15 ± 1.13 cm, $P = 0.34$), left ventricular end-systolic diameter (LVDs) (29.30 ± 4.05 *vs.* 29.77 ± 3.11 cm, $P = 0.47$) and left ventricular posterior wall diastolic diameter (LVPWDd) (8.98 ± 0.95 *vs.* 8.65 ± 0.93 cm, $P = 0.05$) in both the groups. Additionally, we observed a remarkable increase in the maximum P-wave duration (123.42 ± 12.33 *vs.* 108.18 ± 9.07 ms, $P < 0.01$), and P-wave dispersion (47.24 ± 13.61 *vs.* 28.94 ± 9.19 ms, $P < 0.01$) in the test group as depicted in **Table 2**.

Tables 2 Echocardiographic and the P-wave durations and P-wave dispersion with mitral stenosis and control subjects

	Control group (n=62)	Mitral stenosis group (n=62)	*P* value
Echocardiographic parameters			
Mitral valve area (cm^2)	—	1.44±0.47	—
aortic root inside diameter (mm)	31.58±3.58	29.60±3.50	<0.01
pulmonary trunk (mm)	22.23±1.77	24.17±2.78	<0.01
Left atrial diameter (cm)	32.31±4.24	45.00±5.78	<0.01
Pulmonary artery pressure (mmHg)	32.64±2.86	46.68±17.29	<0.01
IVSDd (mm)	9.15±1.13	9.37±1.40	0.34
LVDd (mm)	45.58±5.04	47.57±4.80	0.03
LVDs (mm)	29.77±3.11	29.30±4.05	0.47
LVPWDd (mm)	8.65±0.93	8.98±0.95	0.05
EF (%)	65.13±2.56	63.10±3.05	<0.01
Electrocardiographic parameters			
Maximum P-wave duration (ms)	108.18±9.06	123.42±12.33	<0.01
Minimum P-wave duration (ms)	79.24±10.54	76.18±10.48	0.11
P-wave dispersion (ms)	28.94±9.19	47.24±13.61	<0.01

Note: IVSDd interventricular septum diastolic diameter；LVDd left ventricular end diastolic diameter；LVDs left ventricular end systolic diameter；LVPWDd left ventricular posterior wall diastolic wall diastolic diameter；EF ejection fraction.

3.3 Univariate and multivariate logistic regression analysis of the P-wave duration and the P-wave dispersion in MS

In order to explore the parameters associated with the MS, we performed univariate and multivariate logistic regression analysis for further investigation. Univariate analysis showed that the P-wave duration (OR:1.173, 95% CI:1.106–1.244, $P < 0.01$), and P-wave dispersion (OR:1.150, 95% CI:1.096–1.2081, $P < 0.01$) in the test group (Table 3). Also, as per the multivariate analysis the occurrence of maximum P-wave duration (OR:1.221, 95% CI:1.126–1.324, $P < 0.01$), and P-wave dispersion (OR:1.164, 95% CI:1.094–1.238, $P < 0.01$) were related with the test group (Table 3).

Table 3
Odds ratios for Maximum/Minimum P-wave duration and P-wave dispersion among mitral stenosis *vs.* control.

P-Wave	Univariate		Multivariate	
	OR (95%CI)	P value	OR (95%CI)	P value
Maximum P-wave duration	1.173 (1.106–1.244)	< 0.01	1.221 (1.126–1.324)	< 0.01
Minimum P-wave duration	0.972 (0.939–1.006)	0.11	0.982 (0.945–1.021)	0.35
P-wave dispersion	1.150 (1.096–1.208)	< 0.01	1.164 (1.094–1.238)	< 0.01

3.4 The best threshold of the P-wave duration and the PWD for MS prediction using ROC curve

Since maximum P-wave duration and PWD were closely related to MS, we quantitative analyzed the cut-off values of P-wave duration and PWD for predicting MS via ROC curves. Results showed that the optimal cut-off values were 119.50 ms and 42.50 ms for maximum P-wave duration and PWD, respectively. The AUCs for P-wave duration and PWD were 0.859 ms and 0.865 ms, respectively, indicating well predicting effects of the two factors (Fig. 1)

4. Discussion

The major findings of the current study were as follows: (1) MS patients exhibited a longer maximum P-wave and higher PWD as compared to the healthy individuals; (2) PWD and P-wave duration were strongly correlated with MS. (3) According to the ROC curve, it was found that the cut-off values for maximum P-wave duration and PWD for predicting the MS were 119.50 ms and 42.50 ms for PWD, respectively. These findings may effectively contribute to the early detection of MS, which in turn may help the clinicians to impede the rate of MS progression.

PWD was first defined in 1998 by Dilaveris and his colleague as the difference between the maximum and the minimum P-wave duration in 12-lead ECG [3]. Numerous studies have established the relationship between the PWD and an array of cardiovascular disorders such as paroxysmal atrial fibrillation, hypertension, and MS [5,7–8]. In healthy subjects, it was found that the PWD was correlated with age[9]. Also, the prolongation of P wave duration and the escalated PWD were related to increased risk of AF [3, 5]. Therefore, PWD has been considered as a crucial indicator to predict the AF risk in MS patients with sinus rhythm[5].

AF is a common clinical complication in MS patients. MS patients with AF were showed poor clinical prognosis, which was associated with the damage to the atrial contraction and fast ventricular rate[10].

Furthermore, secondary injury of the mitral valve and the inflammation of the atrium can aggravate the dilation of the left atrium and the degree of myocardial fibrosis[11]. The resulting anatomical abnormalities will lead to electrical heterogeneity, heterogeneous transmission speeds, and heterogeneous refractory phases within the atrial myocardium. It may also be accompanied by the atrial wall fibrosis and discordance of the atrial bundle, which was manifested as the increase of the P-wave duration and the PWD in ECG[2, 10] .

As compared to the healthy individuals, maximum P-wave duration, and PWD in MS patients were notably escalated, which suggested an increased risk of AF. In addition, a possibility of thromboembolism and mortality were significantly elevated in MS patients with AF. Hence, early detection of patients with MS by simple and acceptable method is a crucial step for the screen of MS patients in clinical practices. Previous studies showed some preliminary evidences on the relationship between ECG parameters and MS. Gholam and colleagues[12]found that the maximum P-wave duration was longer in patients with MS than that of matched controls, and the maximum P-wave duration was significantly correlated with the size of left atrium. More importantly, in a study with more than 3 years of long-term follow-up, unal et al. [13] revealed that the P-wave duration and PWD were increased with the development of MS further indicating the essential role of these two factors in the progression of MS. In this study, we revealed that in the absence of an echocardiographic evaluation, a prolonged P-wave duration and PWD would significantly contribute towards the early prognosis in MS patients. Also, a major advantage of this mode of prognosis is the low-cost of technology and the ease of evaluation.

Over the years, researchers have revealed the presence of increased sympathetic activity in MS patients[14, 15]. Moreover, Tukek et al.[16] demonstrated that the enhanced sympathetic excitation results in a remarkable rise in PWD. Besides, previous studies have shown[14] the reduced sympathetic excitation after the mitral valve surgery and the beneficial activity of beta-blockers in MS patients[17]. A chronic administration of beta-blockers could result in the reduced maximum P-wave duration and PWD in MS patients by constraining the sympathetic activity[17]. Thus, these findings suggest that enhanced sympathetic excitation could lead to the prolongation of maximum P-wave duration and PWD in MS patients.

We herein, for the first time, determined the cutoff value for P-wave duration as 119.50 ms and P-wave dispersion as 42.50 ms, for the effective prognosis of MS in the Chinese population. Our unpublished data showed that a regular ECG evaluation of patients with an increased risk of mitral valve abnormalities could delay the progression of mitral stenosis. However, this study demonstrated that the P-wave duration and PWD might not be enough for the prognosis of the degree of mitral stenosis in the Chinese population. Therefore, an in-depth analysis and validation studies are required to determine the predictive efficacy of P-wave duration and the PWD in the MS population. Nevertheless, global access to the affected patient's clinical reports may help to unravel the mechanism of P-wave parameters and to access the increased risk of AF in MS patients.

This study, however, has certain limitations. Firstly, the sample size of the current research is comparatively small. Secondly, this study was a single-centered, observational study, which might have affected the generalizability. Thirdly, the ECG's P-wave calculations were performed manually rather than employing the computer-assisted P-wave calculations. Finally, a selection bias may have occurred due to the delay in recording the onset of paroxysmal AF in the affected individuals.

Conclusions

In summary, our results demonstrate that a longer P-wave duration and a higher PWD are correlated with the increased risk of MS progression. We should pay attention to the regular follow-up to impede the progression of mitral stenosis.

Abbreviations

mitral stenosis=MS; atrial fibrillation=AF; P-wave dispersion=PWD; area under the receiver operating characteristic=AUROC; electrocardiogram=ECG.

Declarations

Ethics approval and consent to participate The study was approved by the Shanghai Chest Hospital's local ethics committee. Written informed consent from all participants was obtained.

Consent for publication Not applicable.

Availability of data and materials The datasets used and/or analysed during the current study are de-identified and available from the corresponding author on reasonable request.

Competing interests The authors declare that they have no competing interests.

Funding Not applicable.

Authors' Contributions

Each author accomplishes the standard for the authorship. WXF and RGL planned and executed this study. WXF, JWL, LXC, WZL, XJW acquired the data. WXF drafted the manuscript. WXF performed the statistical analysis of data. All authors reviewed and accepted the final version of this manuscript.

Acknowledgements Not applicable.

References

1. A Selzer, and K.E. Cohn. Natural history of mitral stenosis: a review. Circulation, 1972. **45**(4): 878-90.

2. P E Dilaveris, E J Gialafos, G K Andrikopoulos, D J Richter, V Papanikolaou, K Poralis, et al.Clinical and electrocardiographic predictors of recurrent atrial fibrillation. Pacing Clin Electrophysiol 2000; 23(3): 352-8.
3. P E Dilaveris, E J Gialafos, S K Sideris, A M Theopistou, G K Andrikopoulos, M Kyriakidis, et al. Simple electrocardiographic markers for the prediction of paroxysmal idiopathic atrial fibrillation. Am Heart J 1998;**135**(5 Pt 1): 733-8.
4. Michalis Efremidis1, Ioannis P Alexanian, Dimitrios Oikonomou, Dimitrios Manolatos, Konstantinos P Letsas, Loukas K Pappas, et al. Predictors of atrial fibrillation recurrence in patients with long-lasting atrial fibrillation. Can J Cardiol 2009; **25**(4): e119-24.
5. K Aytemir1, N Ozer, E Atalar, E Sade, S Aksöyek, K Ovünç,et al. P wave dispersion on 12-lead electrocardiography in patients with paroxysmal atrial fibrillation. Pacing Clin Electrophysiol 2000;23(7): 1109-12.
6. Babak Kazemi, Ali Rostami, Naser Aslanabadi, Samad Ghaffari. Electrocardiographic P-wave Indices as a Useful Tool to Predict Successful Percutaneous Balloon Mitral Valvotomy in Patients with Mitral Stenosis. J Cardiovasc Thorac Res 2014;6(1): 9-14.
7. Hasan Turhan, Ertan Yetkin, Kubilay Senen, M Birhan Yilmaz, Mehmet Ileri, Ramazan Atak, et al.Effects of percutaneous mitral balloon valvuloplasty on P-wave dispersion in patients with mitral stenosis. Am J Cardiol 2002;89(5): p607-9.
8. N Ozer, K Aytemir, E Atalar, E Sade, S Aksöyek, K Ovünç, et al. P wave dispersion in hypertensive patients with paroxysmal atrial fibrillation. Pacing Clin Electrophysiol 2000;23(11 Pt 2): 859-62.
9. Hasan Turhan, Ertan Yetkin, Onur Sahin, Ayse Saatci Yasar, Kubilay Senen, Ramazan Atak,et al. Comparison of P-wave duration and dispersion in patients aged > or =65 years with those aged < or =45 years. J Electrocardiol 2003;36(4): 321-6.
10. Braunwald E. Valvular heart disease, In: Braunwald E, Zipes DP, Libby P. Heart Disease: A textbook of cardiovascular Medicine. 6th ed. Philadelphia: WB Saunders 2001;1643-1653.
11. Roberta Ancona, Salvatore Comenale Pinto, Pio Caso, Giovanni Di Salvo, Sergio Severino, Antonello D'Andrea, et al. Two-dimensional atrial systolic strain imaging predicts atrial fibrillation at 4-year follow-up in asymptomatic rheumatic mitral *stenosis.* J Am Soc Echocardiogr 2013;**26**(3): 270-7.
12. G Reza Rezaian, Sh Rezaian, L Liaghat, N Zare. P-wave dispersion in patients with rheumatic mitral stenosis. Int J Angiol 2007;16(1):20-23.
13. Unal Guntekin1, Yilmaz Gunes, Mustafa Tuncer, Ahmet Gunes, Musa Sahin, Hakki Simsek. Long-term follow-up of P-wave duration and dispersion in patients with mitral stenosis. Pacing Clin Electrophysiol. 2008 Dec;31(12):1620-4.
14. K Ashino, E Gotoh, S Sumita, A Moriya, M Ishii. Percutaneous transluminal mitral valvuloplasty normalizes baroreflex sensitivity and sympathetic activity in patients with mitral stenosis. Circulation 1997;96(10):3443-9.
15. Y Imamura, H Ando, T Ashihara, T Fukuyama. Myocardial adrenergic nervous activity is intensified in patients with heart failure without left ventricular volume or pressure overload. J Am Coll Cardiol

1996;28(2): 371-5.

16. T Tükek1, V Akkaya, S Demirel, A B Sözen, H Kudat, D Atilgan, et al.Effect of Valsalva maneuver on surface electrocardiographic P-wave dispersion in paroxysmal atrial fibrillation. Am J Cardiol 2000;85(7): 896-9, A10.
17. Ali Riza Erbay, Hasan Turhan, Ayse Saatci Yasar, Asuman Bicer, Kubilay Senen, et al. Effects of long-term beta-blocker therapy on P-wave duration and dispersion in patients with rheumatic mitral stenosis. Int J Cardiol 2005 102(1): 33-7.

Figures

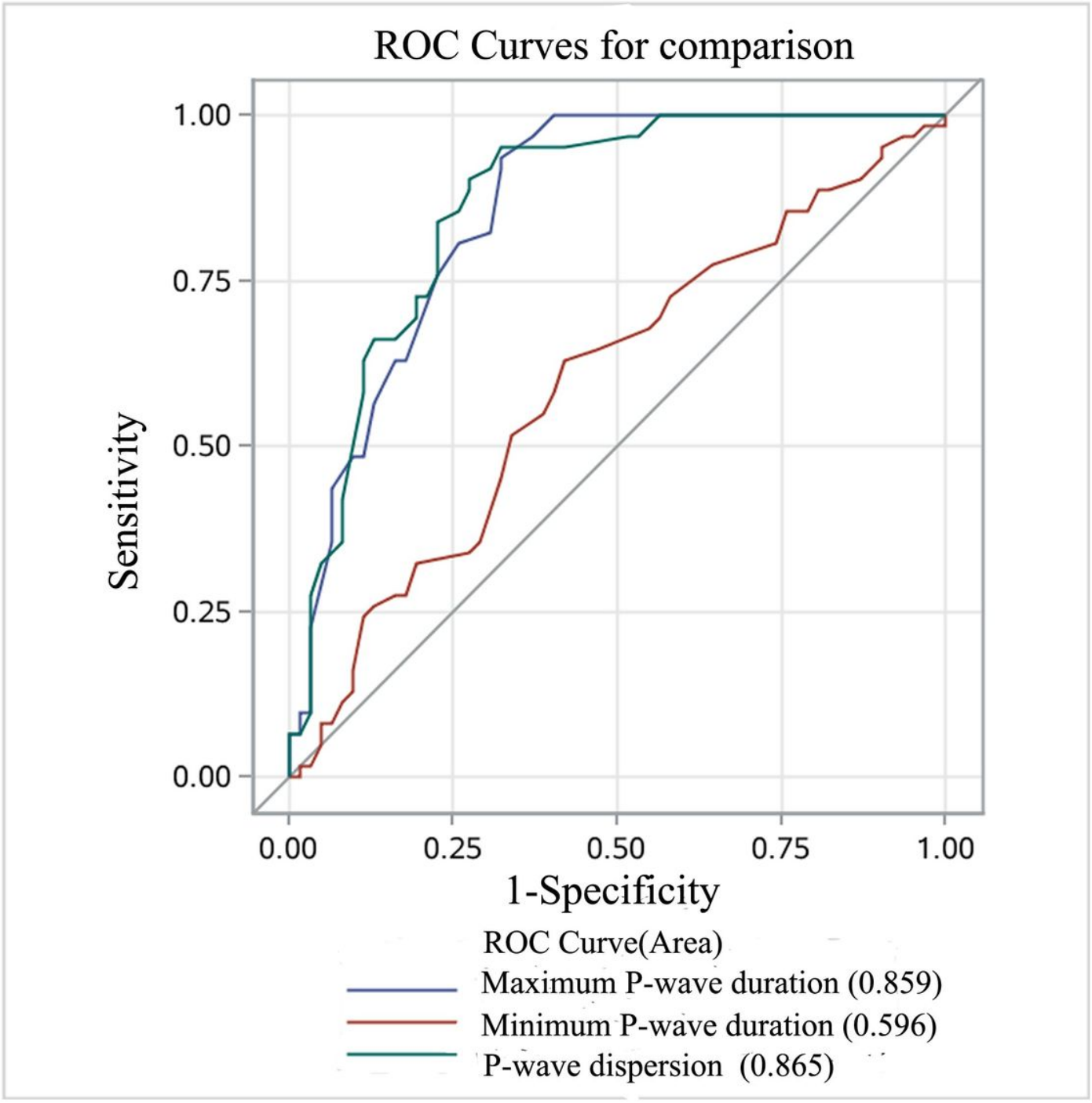


Figure 1

A Receiver Operating Characteristic (ROC) curve for the prediction of mitral stenosis based on the P-wave durations and P-wave dispersion.