P wave duration in the 12 leads of the electrocardiogram and its relationship with interatrial conduction time in patients with paroxysmal supraventricular tachycardias

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ARTICLE INFORMATION

Competing interests
The authors declare no competing interests.

Abbreviations
APs: Accessory pathways
AVNRT: Atrioventricular nodal reentry tachycardia
ICT: Interatrial conduction time
P_{dur}: P wave duration

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ABSTRACT

Introduction: Although some studies relate P wave parameters to different atrial conduction times, they do not consider each electrocardiogram lead separately.
Objectives: To determine the duration of P wave (P_{dur}) in the 12 leads of the electrocardiogram and relate it to the interatrial conduction time.
Methods: We conducted a cross-sectional study in 153 adult patients with confirmed diagnosis of atrioventricular nodal reentry tachycardia (AVNRT) or accessory pathways by invasive electrophysiological study.
Results: When comparing the P_{dur} between arrhythmic substrates by each lead, no significant differences were found, except for V_6. In leads II, III, aVR, aVF, V_1 and V_3-V_6, P_{dur} was correlated with the interatrial conduction time in both arrhythmic substrates. In our multivariate analysis, the P_{dur} was an independent predictor of interatrial conduction times ≥ 95 percentile in inferior wall leads and in V_3, V_5 and V_6. High values of the area under the receiver operating characteristic curve were observed in II (0.950; p<0.001), III (0.850; p<0.001) and V_5 (0.891; p<0.001) leads.
Conclusions: The P_{dur} showed no difference by leads when comparing cases with AVNRT and accessory pathways, except for V_6. Most of the leads were correlated with the interatrial conduction time; P_{dur} was an independent predictor of interatrial conduction times ≥ 95 percentile. Lead II has the greatest discriminatory ability to find prolonged values of interatrial conduction time.
Keywords: P wave duration, Electrocardiogram, Interatrial conduction time, Electrophysiological study, Atrioventricular nodal reentry tachycardia, Accessory pathways

Duración de la onda P en las 12 derivaciones del electrocardiograma y su relación con el tiempo de conducción interauricular en pacientes con taquicardias paroxísticas supraventriculares

Authors' contribution

RCP: Research conception and design; data collection, analysis, interpretation and writing of the manuscript

ECG, MARLC, ELM, GPP, JMCE, FRG: Data analysis, interpretation and writing of the manuscript.

YBM and OCH: References review and help in writing of the manuscript.

All authors critically reviewed the manuscript and approved the final report.

RESUMEN

Introducción: Existen algunos estudios que relacionan parámetros de la onda P con diferentes tiempos de conducción auricular, pero no se han realizado teniendo en cuenta a cada derivación del electrocardiograma.

Objetivo: Determinar la duración de la onda P (P_{dur}) en las 12 derivaciones y relacionarlas con el tiempo de conducción interauricular.

Método: Estudio de corte transversal en 153 pacientes adultos con diagnóstico confirmado de taquicardia por reentrada intranodal (TRIN) o vías accesorias mediante estudio electrofisiológico invasivo.

Resultados: Al comparar la P_{dur} entre sustratos arrítmicos por cada derivación, no existieron diferencias significativas, excepto en V_6. En las derivaciones D_{II}, D_{III}, aVR, aVF, V_1 y de V_3-V_6 la P_{dur} se correlacionó con el tiempo de conducción interauricular en ambos sustratos arrítmicos. En el análisis multivariado, la P_{dur} constituyó un predictor independiente de tiempos de conducción interauricular ≥ 95 percentil, en las derivaciones de cara inferior y en V_3, V_5 y V_6. Se observaron altos valores del área bajo la curva de la Característica Operativa del Receptor en las derivaciones D_{II} (0,950; p<0,001), D_{III} (0,850; p<0,001) y V_5 (0,891; p<0,001).

Conclusiones: No existen diferencias por derivación en la P_{dur} al comparar casos con TRIN y vías accesorias, excepto en V_6. La mayoría de las derivaciones se correlacionaron con el tiempo de conducción interauricular. La P_{dur} fue un predictor independiente de tiempos de conducción interauricular ≥ 95 percentil. La derivación D_{II} presenta la mayor capacidad discriminativa para encontrar valores prolongados del tiempo de conducción interauricular.

Palabras clave: Duración de la onda P, Electrocardiograma, Tiempo de conducción interauricular, Estudio electrofisiológico, Taquicardia por reentrada intranodal, Vías accesorias

INTRODUCTION

Several studies have analyzed the relationship between different P wave indices and atrial conduction times[1-5]; Most of them have done so by means of indirect measurements through echocardiographic modalities coupled with the electrocardiogram. However, the relationship of such times with the P wave duration (P_{dur}) for each of the 12 leads of the electrocardiogram has not been researched, much less using invasive electrophysiological studies that are the gold standard for measuring electrical conduction in the heart. The following research therefore aims to determine the P wave duration in the 12 leads of the electrocardiogram and relate it to the interatrial conduction time (ICT).

METHOD

We conducted a cross-sectional study in 153 patients aged 18-70. Consenting participants were randomly selected from a study population including 286 patients with a clinical history of palpitations and confirmed diagnosis of atrioventricular nodal reentry tachycardia or accessory pathway-mediated tachycardia; who underwent electrophysiological studies and endocavitary ablation at the Department of Clinical Cardiac Electrophysiology and Arrhythmology of the *Hospital Universitario Cardiocentro Ernesto Guevara*, in Santa Clara, Cuba, over the period June 2017 to February 2020.

The electrophysiological study participants were fasted for 8 hours and were off anti-arrhythmic medication for at least 5 or more drug half-lives. All cases were diagnosed with a structurally and functionally normal heart by transthoracic echocardiography.

Exclusion criteria
Patients with the following characteristics were excluded:
- Having more than two electrocardiographic leads that would not allow for P wave measurement or any channel of the atrial intracavitary recordings with poor signal quality.
- Having permanent ventricular pre-excitation, as it makes it difficult for the P wave end to be measured.

Study variables

P_{dur}: Refers to P wave duration. It was measured, in milliseconds (ms), in each of the 12 leads of the electrocardiogram.

ICT: Refers to interatrial conduction time. It was obtained by determining the P-A interval in the distal coronary sinus, which is the time elapsed between the beginning of the P wave and the beginning of the local bipolar electrogram recording obtained from the distal (1-2 pair) of a BIOTRONIK decapolar catheter; which was introduced from the coronary sinus to the left lateral mitral annulus (with a 5 mm spacing between electrodes of the same pair, and a 10 mm spacing between pairs)[6,7]. This 1-2 pair recorded the local activation of the lateral left atrium.

Technique and procedure

All measurements were performed by an experienced electrophysiologist to avoid interobserver error and blinding of data in each case. The patients were awake and without any anesthetic or iso-

prenaline effect before the application of radiofrequency in a multichannel EP TRACER polygraph from BIOTRONIK, using a manual electronic caliper.

Three complexes were always recorded in a row in each electrocardiographic and electrophysiological measurement and then averaged. Electrocardiographic recordings were obtained with a scanning speed of 50 mm/s and amplification of 20 mm/mV. The beginning and end of the P wave were defined as the points where the initial and final deflection of the P wave intersected the isoelectric line. If the beginning or end of the P wave was not clearly visualized, the lead was excluded. A scanning speed of 300 mm/s was used in the electrophysiological measurements.

The diagnosis of AVNRT was confirmed by induced tachycardia in all cases. The presence of APs was demonstrated by revealing abnormal retrograde conduction through the pathway by means of stimulation from the right ventricular apex; furthermore, orthodromic tachycardia could be induced in most
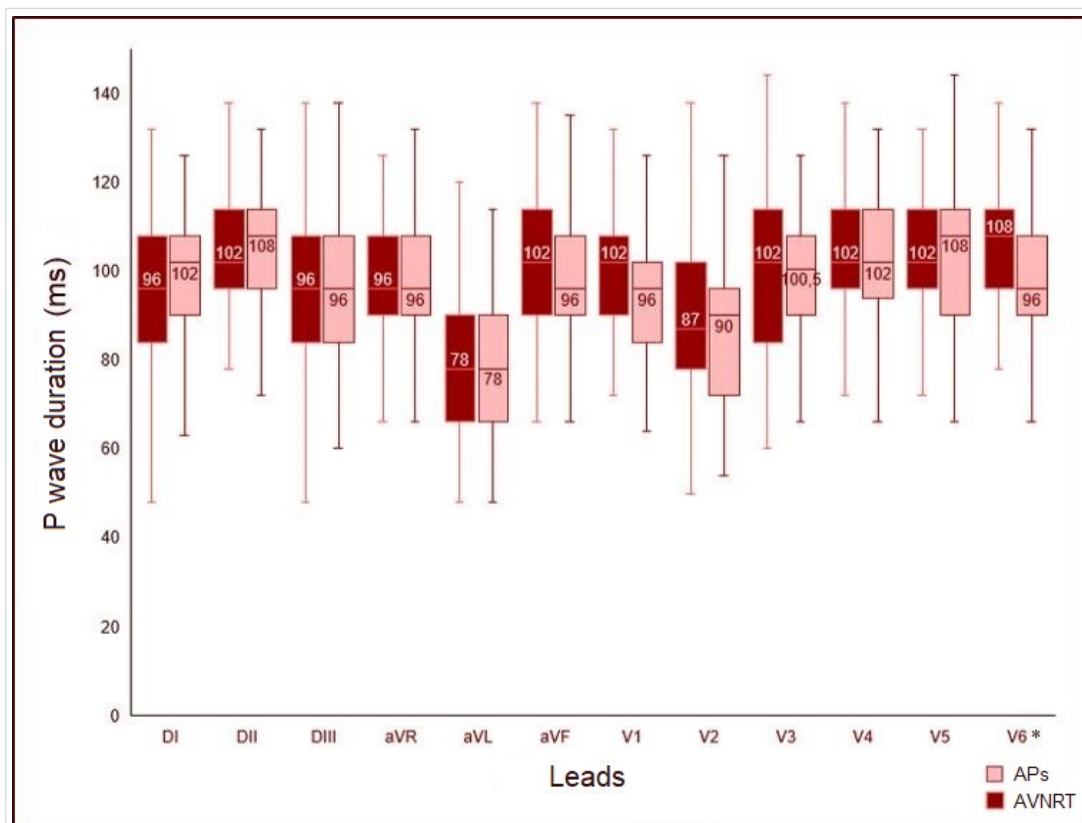

Figure 1. Box plot showing P wave duration in the 12 leads of the electrocardiogram and by arrhythmic substrates.
* Only significant comparison between arrhythmic substrates (p=0.006).
The median, the 25th and 75th percentiles, as well as the minimum and maximum values are displayed.
AVNRT, atrioventricular nodal reentry tachycardia; APs: accessory pathways.

cases.

Statistical analysis and processing

Statistical analysis was performed using the SPSS software, version 21.0. The Kuskal Wallis test was used to compare continuous variables from 3 or more independent samples, after verifying the lack of normality in the data using the Kolmogorov Smirnov test. Subsequent analyzes, if H_0 was rejected, were carried out using the Dunn Bonferroni test.

These data were presented as median, first and third quartiles. To determine the degree of association between the variables, the Pearson correlation coefficient was used. Multivariate analysis was performed through binomial logistic regression. The P_{dur} discriminant ability to find cases with ICT values ≥95 percentile was determined by means of the Receiver Operating Characteristic curves. A level of p<0.05 was considered significant.
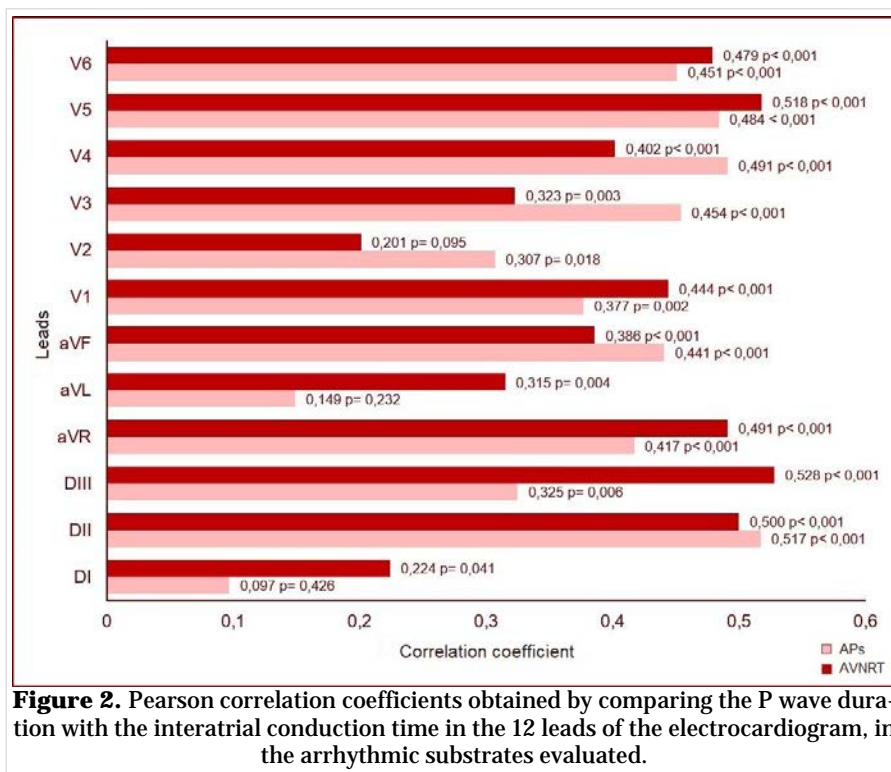

Figure 2. Pearson correlation coefficients obtained by comparing the P wave duration with the interatrial conduction time in the 12 leads of the electrocardiogram, in the arrhythmic substrates evaluated.

RESULTS

Figure 1 presents the median P_{dur} in the 12 leads of the electrocardiogram, as well as the interquartile interval and the maximum and minimum values in patients with APs and AVNRT. The aVL lead had the lowest median P_{dur} (p<0.001) among all leads, in both types of arrhythmic substrates. In the AVNRT group, lead V_6 had the highest median (108 ms), which did not show significant differences when compared with leads II, aVF, V_1, V_3, V_4 and V_5, which showed a median of 102 ms. In the APs group, leads II and V_5 had the highest median P_{dur} with a value of 108 ms, which was not statistically significant (p<0.05) when compared with that observed in leads I and V_4 (102 ms). No significant differences were found when P_{dur} was compared between arrhythmic substrates for each lead, except in V_6, where it was higher in the cases with AVNRT (AVNRT 108 ms vs. APs 96 ms; p= 0.006).

In leads II, III, aVR, aVF, V_1 and V_3-V_6, P_{dur} correlated with ICT in both groups (**Figure 2**). The strength of the correlations ranged from weak to moderate. In patients with APs, the lead II showed the highest correlation coefficients (r=0.517; p<0.001) and V_5 (r=0.484; p<0.001), a finding very similar to that found in patients with AVNRT in leads II (r= 0.500; p<0.001), D_{III} (r=0.528; p<0.001) and V_5 (r=0.518; p<0.001). In leads I and aVL, P_{dur} and ICT only correlated in cases with AVNRT, while in V_2 they only correlated in patients with APs.

The multivariate analysis of binomial logistic regression applied for each lead and controlled for potential confounders, such as age, types of arrhythmic substrates, and high blood pressure, showed that P_{dur} was an independent predictor of ICT values ≥95 percentile in the inferior wall leads. (II, III, and aVF) and in V_3, V_5 and V_6 (**Table**).

Regardless of the types of arrhythmic substrates, P_{dur} has a high discrimination ability to find cases with ICT ≥95 percentile in the analysis of the receiver operating characteristic curve. Leads II, III and V_5 presented the largest areas under the curve (0.950, 0.850 and 0.891; respectively), especially lead II, which reached a value almost equal to 1 (**Figure 3**).

By using a cut-off value ≥112.5 ms, a sensitivity of 100% and specificity of 69.4% were achieved in lead

Table. Results of the multivariate logistic regression analysis for P wave duration as a predictor variable and interatrial conduction time ≥95 percentile as dependent, adjusted for age, high blood pressure and types of arrhythmic substrates.

P wave duration	OR	CI 95%	P value
P_{dur} in lead I	1.021	0.965-1.081	0.465
P_{dur} in lead II	1.168	1.061-1.286	0.002
P_{dur} in lead III	1.105	1.034-1.181	0.003
P_{dur} in aVR	1.066	0.999-1.137	0.055
P_{dur} in aVL	1.024	0.956-1.097	0.500
P_{dur} in aVF	1.078	1.010-1.150	0.024
P_{dur} in V_1	1.005	0.936-1.080	0.883
P_{dur} in V_2	1.005	0.916-1.104	0.910
P_{dur} in V_3	1.078	1.022-1.136	0.005
P_{dur} in V_4	1.053	0.998-1.112	0.061
P_{dur} in V_5	1.106	1.034-1.184	0.004
P_{dur} in V_6	1.085	1.018-1.157	0.012

CI, confidence interval; OR, odds ratio; P_{dur}, P wave duration.

II, and by taking a value ≥127 ms, specificity is improved (sensitivity 83.3%; specificity 99.9%). The best cut-off value in leads III (sensitivity 100%, specificity 87.7%) and V_5 (sensitivity 100%, specificity 73.1%) was ≥111 ms (data not presented in tables or graphs).

DISCUSSION

P wave duration expresses the time required for depolarization of the right and left atria[8]. Lead aVL belongs to the frontal plane. Its position in the hexaxial system could explain why it was the shortest lead in our study. If we take into account that the electrical axis of the P wave is approximately +60° in the frontal plane[9,10] and that it would keep a 90° separation with respect to aVL, a lack of inscription of at least some portions of the P wave would necessarily occur.

It is well known in electrocardiography that when a vector perpendicularly transits to a given lead, such a vector is not recorded. Carmona *et al*[11] found that aVL was the lead with the shortest P wave duration in a series of high-performance soccer players, which reached an average value of 69.64 ± 22.63 ms. However, Gialafos *et al*[12], when studying 1.353 young men belonging to the Greek air force, found that lead V_1 was the one that most frequently presented the shortest P wave duration, followed by V_2 and aVL, with respective prevalences of 25.3%, 18.2% and 15.7%. In the same study, the P wave of longest duration was found in leads II, V_6, V_3 and V_4 with prevalences of 16.3%, 12.5%, 11.5% and 11.5%, respectively.

The P wave is the most recognized non-invasive marker for atrial conduction[13]. Increases in P_{dur} have been shown to reflect increases in the duration of intraatrial and interatrial conduction times[14]. Josephshon[7] considers that the right intraatrial conduction
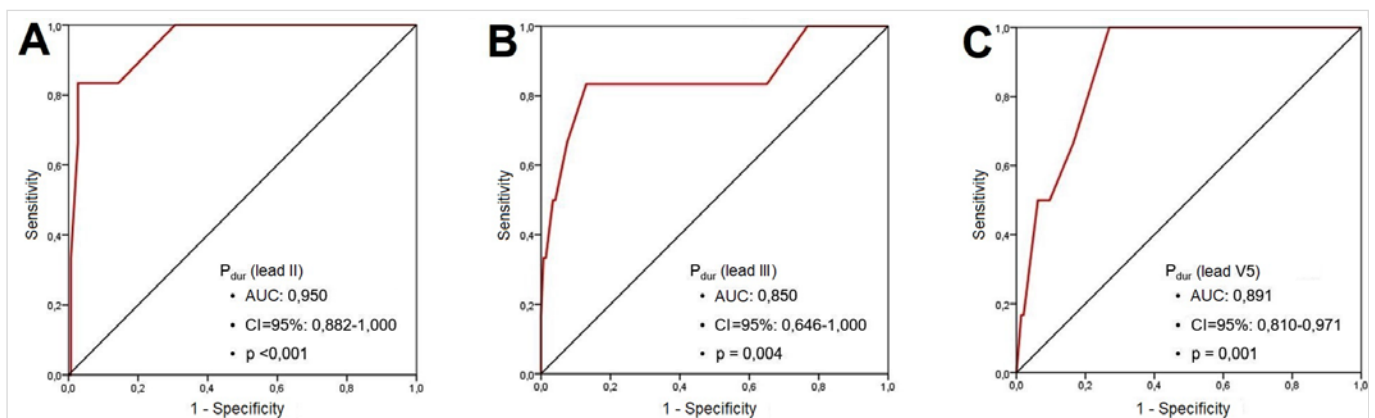

Figura 3. Best Receiver Operative Characteristic curves showing the relationship in all patients between sensitivity and specificity through all possible values of P wave duration, defining patients with interatrial conduction times ≥95 percentile. Leads II (**A**), III (**B**) and V_5 (**C**) of the electrocardiogram.

time does not correlate with P_{dur}, unlike what may occur with ICT. To our knowledge, there are no studies that relate the P wave to the ICT in each of the twelve leads of the electrocardiogram. Previous publications have been based on indices derived from the P wave, mainly its dispersion[5,15 17].

The results presented corroborate the previous findings obtained by Josephson[7], and add that this is true in both patients with AVNRT and APs. Furthermore, they reveal weak to moderate correlation forces in these patients with normal atria.

CONCLUSIONS

There are no differences by lead in the P wave duration when comparing cases with intranodal reentry tachycardia and accessory pathways, except in V_6. In leads II, III, aVR, aVF, V_1 and V_3 V_6, the P wave duration was correlated with the interatrial conduction time in both arrhythmic substrates. The P wave duration was an independent predictor of values of interatrial conduction time ≥95 percentile, in the inferior wall leads and in V_3, V_5 and V_6. Lead II shows the greatest discriminatory ability to find prolonged values of interatrial conduction time.

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