

Diagnostic Accuracy of the P Wave in the Lewis and Gallop Leads for Atrial Enlargement Detection

Carlos Henrique Miranda¹, Gustavo P Gerolim², Ana Marta Salgado Gali³, Antônio Pazin-Filho¹

¹Universidade de São Paulo – Faculdade de Medicina de Ribeirão Preto – Departamento de Clínica Médica – Divisão de Emergências Clínicas – Ribeirão Preto, SP – Brazil

²Universidade de São Paulo – Hospital das Clínicas – Serviço de Ecocardiografia – Ribeirão Preto, SP – Brazil

³Universidade de São Paulo – Faculdade de Medicina de Ribeirão Preto – Departamento de Clínica Médica – Divisão de Cardiologia – Ribeirão Preto, SP – Brazil

Abstract

Background: The diagnostic accuracy (DA) of the conventional electrocardiogram (ECG) for detecting atrial enlargement (AE) is low. Lewis (L) and Gallop (G) enable better viewing the P wave in the ECG.

Objective: Checking whether the P wave parameters in the leads of Lewis and Gallop increase the diagnostic accuracy of the conventional ECG AE criteria.

Methods: The P wave characteristics in the L and G leads were standardized in 27 healthy individuals. The percentile of 99 was considered as limit of normality for those parameters. These new criteria were evaluated in 117 patients through conventional ECG and the L and G leads. The atrial sizes under the echocardiogram were considered as golden standard for defining the AE. The area under the ROC (receiver operating characteristic) curve (AUC) was used for determining the DA of each parameter.

Results: Conventional ECG presented low DA for detecting the AE. Morris index was the only showing significant DA: AUC 0.57 (95%CI: 0.48-0.66); p=0.03. The inclusion of the P wave >100 ms (L and G) has not increased the DA for detecting left AE compared to the traditional criteria: AUC 0.58 (95%CI: 0.50-0.65) vs. AUC 0.57 (95%CI: 0.49-0.65); p=0.80. Including P wave with amplitude >2 mm (L) and/or >3 mm (G) has not increased DA for detecting right AE either: AUC 0.53 (95%CI: 0.46-0.61) vs. AUC 0.53 (95%CI: 0.45-0.60); p=0.31.

Conclusion: Including the P wave in the accessory leads of L and G did not result in increment of DA for detecting AE.

Keywords: Electrocardiography; Atrial function, left; Atrial function, right

Introduction

Detecting atrial enlargement, especially that of the left atrial function, is important during the clinic evaluation, considering that its presence may identify individuals with higher risk of developing atrial fibrillation¹⁻³. The electrocardiographic criteria normally used for evaluating atrial enlargement present low diagnostic accuracy⁴. Lewis (L) and Gallop (G) accessory leads were described in the past century and enable better viewing the P wave

in the surface electrocardiogram. Those bipolar accessory leads are attained by placing the electrodes of the upper limbs on the chest, the electrode of the right arm being placed on the second right parasternal intercostal space, and the left arm electrode, on the fourth right parasternal intercostal space in Lewis, and on the left parasternal in Gallop⁵.

The objective of this study was verifying whether the use of the P wave electrocardiographic parameters attained

Corresponding author: Carlos Henrique Miranda

Rua Bernardino de Campos, 1000 – Centro – 14015-130 – Ribeirão Preto, SP – Brazil

E-mail: chmiranda@fmrp.usp.br

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ABBREVIATIONS AND ACRONYMS

- *AE* – atrial enlargement
- *AUC* – area under the curve
- *DA* – diagnostic accuracy
- *ECG* – electrocardiogram
- *G* – Gallop
- *L* – Lewis
- *LVEF* – left ventricular ejection fraction
- *ROC* – receiver operating characteristic

from the accessory leads of Lewis and Gallop increases the diagnostic accuracy of the traditional electrocardiographic criteria used for finding the atrial enlargements.

Methods

Comparative transversal cut study on diagnostic methods performed in the Emergency Unit of Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo (HC-FMRP-USP), from June to December 2011.

The study was performed in two consecutive phases. The first phase included 27 healthy male and female individuals, with age >18 years, that were subject to the conventional electrocardiogram (ECG) with 12 leads together with Lewis and Gallop leads, for standardizing the reference values in relation to the morphology, duration and amplitude of the P wave in those two accessory leads. The second phase included 117 male and female patients, aged >18 years, admitted under several diagnoses in the Coronary Unit of the Emergency Unit, HC-FMRP-USP. Those patients were also subject to the conventional ECG with 12 leads in association to the accessory leads of Lewis and Gallop, together with a two-dimensional transthoracic echocardiogram for quantifying the sizes of the heart chambers and the left ventricular function.

For determining the sensitiveness and the specificity of the electrocardiographic parameters for detecting the left and right AE, the measures of the left and of the right atrium were considered by the two-dimensional transthoracic echocardiogram as the golden standard for determining the enlargement of those chambers.

The project of this study was approved by the Ethics Committee of Hospital das Clínicas da FMRP-USP under no. 2802/2011. All patients included signed an Informed Consent Form.

Analysis of the 12-lead conventional ECG

The entire layout was performed by the Pager Writer Trim electrocardiograph (Philips, Andover, MA, USA)

with speed at 25 mm/s and amplitude of 10 mm/mV and read by a trained cardiologist.

This study considered as electrocardiographic criteria for defining the enlargement of the left atrium, the P wave duration at the DII lead >120 ms, the presence of notch in the P wave at distance >40 ms between the two components and the negative component of the P wave at the lead V1 >1 mm² (Morris index)⁶. For defining the enlargement of the right atrium, the P wave amplitude at the DII lead >2.5 ms, or the presence of a positive component of the P wave at the lead V1 >1.5 mm were considered⁷.

Analysis of the Lewis and Gallop accessory leads

The entire layout was also performed by the Pager Writer Trim electrocardiograph (Philips, Andover, MA, USA) with speed at 25 mm/s and amplitude of 10 mm/mV and read by a trained cardiologist. These accessory derivations were attained through the electrodes of the DI bipolar lead of the conventional electrocardiogram. The electrode corresponding to the right arm (positive) was positioned together with the right sternal edge on the second intercostal space, and the electrode corresponding to the left arm (negative) was positioned in the fourth right parasternal intercostal space in the Lewis lead and left parasternal, in the Gallop lead. Only the lead corresponding to DI was analyzed. The P wave in those leads was assessed as to its morphology, duration in milliseconds and amplitude in millimeters⁵.

The analysis of the data attained in this study standardized the percentile 99 (P_{99}) as reference of normality for the duration and amplitude of the P wave attained from the accessory leads of Lewis and Gallop of the healthy volunteers.

Analysis of the two-dimensional transthoracic echocardiogram

The atrial sizes attained by the two-dimensional transthoracic echocardiogram Doppler were defined as golden standard for the diagnosis of enlargement of right and left atrium. Those tests were performed with the device HD11 XE (Philips, Bothell, WA, USA) by trained professionals. The dimension of the left atrium was attained by means of the M-mode or by the two-dimensional anteroposterior linear dimension

in the longitudinal parasternal projection. The measurement by the M-mode was attained by the distance between the upper edge of the aorta posterior wall and the upper edge of the left atrium posterior wall. A dimension >40 mm was considered as dilation of left atrium⁸. The evaluation of the size of the left atrium applied the measurement of its area, attained by the planimetry of that chamber in the apical four-chamber projection. The area was dashed in the end of the ventricle systole, from the side edge of the tricuspid valve, along the right atrium endocardium until the septal edge of the valve ring, except for the upper and lower vena cava and the right atrial appendix. An area over 18 cm^2 was considered as indication of increase of left atrium⁸.

Statistical analysis

The continuous variables were expressed as mean \pm standard deviation. Categorical variables were expressed as percentage. The sensitiveness and specificity were calculated for each electrocardiographic parameter analyzed comparing them with the echocardiographic parameters considered as golden standard.

For determining the diagnostic accuracy, the ROC (receiver operating characteristic) curve was created for each electrocardiographic parameter analyzed, by calculating the area under it (AUC). The construction of the ROC curve and the comparison of differences between the curves required the use of the statistics software STATA version 13 (College Station, Texas, USA). The p-value <0.05 was considered as statistically significant.

Results

The standardization of the reference values of P wave in the Lewis and Gallop leads was performed in 27 healthy individuals, with mean age of 31.0 ± 11.0 years, 70.0% of them being male. The 12-lead electrocardiogram presented mean heart rate of 66 ± 9 bpm, mean PR interval of 151 ± 18 ms and mean QRS duration of 89 ± 8 ms.

The P wave in the Lewis lead presented positive or isoelectric morphology, mean duration of 37 ± 35 ms and mean amplitude of 0.56 ± 0.56 mm. The percentiles 99 for duration and amplitude were, respectively, 100 ms and 2 mm in this lead. The P wave in the Gallop lead

presented positive morphology, mean duration of 69 ± 20 ms and mean amplitude of 1.24 ± 0.60 mm. The percentiles 99 for duration and amplitude were, respectively, 100 ms and 3 mm in this lead.

Table 1 shows the clinic and laboratory characteristics of the patients included in the second phase of the study. It featured 117 patients with mean age of 59.0 ± 13.0 years, and predominance of the male sex (60.0%). The diagnosis of coronary artery disease was the most frequent (83.0%), with a small percentage of patients with valve disease (3.0%), Chagas heart disease (4.0%) and dilated cardiomyopathy (5.0%).

The mean left ventricular ejection fraction (LVEF) of the patients included was $52\pm 15\%$, and 36 (31.0%) patients presented LVEF $<50\%$. By using the traditional electrocardiographic criteria, the presence of left atrial enlargement was observed in 25 (21.0%) patients and the presence of right atrial enlargement, only in 1 (0.8%) patient. By using the echocardiographic criteria, the left atrial enlargement was defined in 53 (45.0%) patients and right atrial enlargement, in 13 (11.0%) patients.

Diagnostic accuracy of the electrocardiographic parameters

The analysis of the traditional electrocardiographic parameters for the left atrial enlargement found low sensitiveness of those criteria (2-26%) related to high specificity (89-100%) under the criteria applied. Only the Morris index showed diagnostic accuracy with statistical significance, with the area under the curve (AUC) of 0.57 (95%CI: 0.48-0.66); $p=0.03$; but, still, with a very limited value. The other criteria have not shown diagnostic accuracy with statistical significance: the notch in the P wave with AUC of 0.54 (95%CI: 0.45-0.64); $p=0.15$ and the wave duration $P>120$ ms with AUC of 0.50 (95%CI: 0.41-0.60); $p=0.31$ (Table 2).

Taking the electrocardiographic criteria into consideration in the accessory leads of Lewis and Gallop for evaluating the left atrial enlargement, the wave duration $P>100$ ms in the Lewis leads showed sensitiveness of 0.0% and a specificity of 100% with AUC of 0.50 (95%CI: 0.40-0.59); $p=1.00$. The wave duration $P>100$ ms in the Gallop lead showed sensitiveness of 10% and a specificity of 92% with AUC of 0.50 (95%CI: 0.41-0.60); $p=0.75$ (Table 2).

Table 1
Demographic clinic, electrocardiographic and echocardiographic characteristics of the patients studied (n=117)

Demographic characteristics	Age (years) mean±SD	59.0±13.0
	Male n (%)	70 (59.82)
Clinic characteristics	Arterial hypertension n (%)	98 (83.76)
	Dyslipidemia n (%)	67 (57.26)
	Diabetes mellitus n (%)	38 (32.47)
	Myocardial infarction n (%)	72 (61.53)
	Angina pectoris n (%)	25 (21.36)
	Valve disease n (%)	4 (3.41)
	Chagas heart disease n (%)	5 (4.27)
	Dilated cardiomyopathy (%)	6 (5.12)
Electrocardiographic characteristics	HR (bpm) mean±SD	74.0±16.0
	PR Interval PR (ms) mean±SD	164,0±26,0
	QRS duration (ms) mean±SD	9.0±25.0
	L bundle branch block n (%)	8 (6.83)
	R bundle branch block n (%)	7 (5.98)
	Ventricular enlargement n (%)	33 (28.20)
	L atrial enlargement n (%)	25 (21.36)
	R atrial enlargement n (%)	1 (0.85)
Echocardiographic characteristics	L atrium > 40 mm n (%)	53 (45.29)
	Right atrial enlargement n (%)	13 (11.11)
	L atrium diameter (mm) mean±SD	41.0±8.0
	L ventricle diameter (mm) mean±SD	49.0±10.0
	LVEF (%) mean+SD	52.0±15.0
LVEF <50% n (%)	36 (30.76)	

HR – heart rate; L – left; R – right; LVEF – left ventricular ejection fraction; SD – standard deviation

Table 2

P wave changes characteristics in the electrocardiogram at rest, Lewis and Gallop leads for the diagnosis of left and right atrial enlargements

Parameters	Prevalence (%)	Sensitiveness (%)	Specificity (%)	AUC (95%IC)	z-statistic	p-value	
Morris Index	18	26	89	0.57 (0.48-0.66)		0.03	
P wave notch	15	21	89	0.54 (0.45-0.64)	1.43	0.15	
Duration P>120 ms (DII)	01	02	100	0.50 (0.41-0.60)	1.00	0.31	
Left atrial enlargement	Duration P>100 ms (Gallop)	09	10	92	0.50 (0.41-0.60)	0.30	0.75
	Duration P>100 ms (Lewis)	00	00	100	0.50 (0.40-0.59)	-	1.00
	Three traditional criteria	21	30	86	0.58 (0.48-0.67)	2.00	0.03
	All associated criteria	26	36	81	0.57 (0.50-0.68)	2.00	0.03
Right atrial enlargement	Amplitude P> 2.5 mm (DII)	01	08	100	0.53 (0.44-0.63)	1.00	0.31
	Positive component V1>1.5 mm	00	00	100	0.50 (0.40-0.59)	-	1.00
	Amplitude P> 3.0 mm (Gallop)	02	08	99	0.53 (0.43-0.62)	0.86	0.38
	Amplitude P> 2.0 mm (Lewis)	00	00	100	0.50 (0.40-0.59)	-	1.00

AUC – area under the ROC curve; CI – confidence interval

Adding the parameters observed in the Lewis and Gallop leads to the traditional parameters for evaluating the left atrial enlargement has not shown diagnosis increment in relation to the three traditional parameters already used for that evaluation, with similar areas under the ROC curve, 0.57 (95%CI: 0.50-0.68) vs. 0.58 (95%CI: 0.48-0.67); p=0.80, respectively.

Regarding the traditional criteria for evaluating the left atrial enlargement, low sensitiveness (0-8.0%) and high specificity (100%) were observed as well, but none of those criteria presented statistical significance. The wave amplitude P>2.5 mm showed AUC of 0.53 (95%CI: 0.44-0.63); p=0.31 and the positive component in V1 >1.5 mm an AUC of 0.50 (95%CI: 0.40-0.59); p=1.00.

Regarding the electrocardiograph criteria in these same leads for evaluating the right atrial enlargement, the wave amplitude P>2.0 mm in the Lewis lead showed AUC of 0.50 (95%CI: 0.40-0.59); p=1.00 and the wave amplitude P>3.0 mm of the Gallop lead showed AUC of 0.53 (95%CI: 0.43-0.62); p=0.38.

Adding the parameters observed in the Lewis and Gallop leads to the traditional parameters for evaluating the right atrial enlargement in relation to the traditional parameters has not shown diagnosis increment as well, with similar areas under the ROC curve: 0.53 (95%CI: 0.46-0.61) vs. 0.53 (95%CI: 0.45-0.60); p=0.31.

Discussion

This study confirmed previous findings, proving that the traditional electrocardiographic criteria for defining the left and right atrial enlargement have low diagnostic accuracy. The Morris index was the only with diagnostic accuracy relevant for the evaluation of left atrial enlargement, but, still, with limited value. The inclusion of the P wave electrocardiographic parameters analyzed in the accessory leads of Lewis and Gallop have not incremented the diagnostic accuracy of the traditional electrocardiographic criteria in the evaluation of the left and right enlargements.

Several studies have compared the traditional electrocardiographic parameters to the two-dimensional echocardiogram data for evaluating the atrial enlargements, in especial for evaluating the left atrial enlargement. This comparison applied the size of the left and the right atrium in the older studies and the volumes of those chambers in the most recent ones. Most of the studies found low sensitiveness of the electrocardiographic parameters for evaluating the atrial enlargement. Other studies, by using the ROC curves, have also shown areas under the curve very close to those found in this study, confirming the low diagnostic accuracy of those criteria, leading to the questioning of the validity of its clinical utilization⁹⁻¹⁹.

While comparing the different electrocardiographic criteria, there is a trend in some studies of showing that the Morris index seems to be the one with best diagnostic accuracy for finding the left atrial enlargement, as found in this study, as it is the only showing significant diagnostic accuracy for evaluating the left atrial enlargement¹². But, although it presents statistical significance, the Morris index showed an AUC of 0.57, which is considered as a poor accuracy for a diagnosis exam, and, therefore, of limited clinic significance.

Recent data, using other image method for quantifying the atrial sizes, such as the heart resonance imaging, have also reproduced results similar to those observed with the use of echocardiogram, that is, low diagnostic accuracy of the electrocardiographic parameters²⁰.

The Lewis and Gallop accessory leads have been used for a better view of P waves during tachycardia events with wide QRS largo, helping the evaluation of the presence of atrioventricular dissociation and, this way, confirming the ventricular source of arrhythmia^{5,21}. No

study was found in the medical literature that has evaluated the use of the electrocardiographic parameters of the P wave in the Lewis and Gallop leads for detecting atrial enlargements. The use of this bipolar lead was expected to, while reproducing the atrial depolarization angle, render a better record of the P wave, and, this way, contribute to the increment of the diagnostic accuracy of the conventional electrocardiograph for evaluating the atrial enlargements. However, that fact could not be confirmed by the results of this study.

Some limitations were found in this study: the size of the atrial cavities in the two-dimensional mode was used as golden standard for defining the enlargement of the left atrium. Currently, the use of the left and right atrium volumes indexed for the body surface is recognized as the most adequate echocardiograph parameter for performing that evaluation⁸, however, that parameter was not used. On the other hand, with the use of this more current recommendation, an increase of the echocardiographic detection of the right and left atrial enlargement would be expected, and, if it was really observed, the electrocardiographic parameters sensitiveness would be even more limited for detecting the atrial enlargements.

This study evaluated a restricted population, most of the patients having diagnosis of coronary arterial disease, therefore, the results cannot be extrapolated to other populations, as, for example, patients with valve disease or congenital heart disease.

Conclusions

The traditional electrocardiographic criteria for evaluating atrial enlargement present low diagnostic accuracy. The Morris index seems to be the parameter with the best diagnostic accuracy for detecting the left atrial enlargement, but, still, with limited value. Including the P wave in the accessory leads of Lewis and Gallop did not result in increment of the diagnostic accuracy for detecting atrial enlargements.

Potential Conflicts of Interest

This study has no relevant conflicts of interest.

Sources of Funding

This study had no external funding sources.

Academic Association

This study is not associated with any graduate programs.

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