Exaggerated Amplitude and Peak Location of Ta Wave in Tachycardia as an Indicator for Atrial Disorders

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Abstract

In Standard 12-Lead Electrocardiogram (ECG) of Sinus Rhythm (SR) volunteers, the atrial repolarization (Ta wave) as a possible indicator for atrial-related diseases is undermined. The presence of Ta wave in exercise stress ECG has been noted previously, however its manifestation during SR is limited in Standard 12-lead system. This study delineates and compares the characteristics of the Ta wave in Sinus Tachycardia (ST) with the SR in terms of amplitude and Ta peak location using the Modified Limb Lead (MLL) system. MLL was recorded for eight SR and fifteen ST volunteers (mean age of 24 years). P-R and S-T segment amplitudes were measured and analyzed. Ta wave-related impact on P-R and S-T segment have been noted and found a 41.60 % increase in P-R_{ST} to P-R_{SR} and 49.60% in S-T_{ST} to S-T_{SR} using absolute values of P-R and S-T segments. Moreover, the Ta wave peak can be predicted with the change in morphology of the P-R and S-T segments. Determination of Ta wave peak may help to delineate atrial-related disease conditions. A detailed study on Ta wave induced S-T segment depression and elevation helps decrease the false-positive detection of myocardial ischemia and infarction.

1. Introduction

Atrial repolarization (Ta wave) has been the least studied wave of ECG and its potential to predict cardiac disorders have also been long overlooked. It is because of this reason that it scarcely manifests itself in the most used standard 12-lead system. The Ta wave is hidden within the ventricle depolarization and repolarization waves due to its low amplitude hence perceived as dormant. However, in a few disease conditions, the Ta wave is visible in standard 12-lead ECG recording, as the ventricles do not propagate electric currents; hence the ventricular components (QRS complex and T wave) are absent, i.e., Atrioventricular Block (AVB). Ta wave and its characteristic changes with respect to heart conditions are rarely studied. Hence, the role of Ta wave as a potential indicator for detecting arrhythmias is undermined.

A study [1] used electrocardiographic imaging and stated that the propagation pattern of repolarization electric waves in atria and ventricles is opposite. The Ta wave begins from the SA node, similar to the depolarization wave, and the ventricle repolarization wave begins from the apex of the heart. This finding indicated the Ta wave as a negative wave in succession to the atrial depolarization, P wave. Hence, the P and Ta waves are opposite [2,3] and Ta wave duration is 2-3 times the P wave, which is generally noted in AVB. However, whether the Ta wave characteristics in diseased condition are normal or exaggerated and if exaggerated then to what extent is not yet established. [4] stated the Ta wave as one of the unexplored portions of ECG. Another study [5] stated the location of Ta wave peak might help in the detection of atrial fibrillation.

A study [6,7,8] employed a novel Modified Limb Lead (MLL) ECG system and noted the 'observable Ta wave' in Sinus Rhythm (SR) of duration 109 ± 4.7 ms. Hence, the MLL system also employed in this study helps to witness and measure the Ta wave features by comparing the P-R and S-T segment amplitude for the Sinus Rhythm (SR) and Sinus Tachycardia (ST) ECG recordings which may assist in the early determination of disease. The P wave of MLL ECG is approximately equivalent to the R wave. Therefore, the MLL system is optimum for studying the atrial aspects, including the repolarization wave of the atria. This study records the ST ECG after a stressful exercise, thus the impact of stress on heart is noted through Ta wave. Moreover, heart rate in the range of ST condition, achieved during rest condition without prior exercise, is also noted in a study [9].

This study extending the MLL system application, determined the exaggerated amplitude of Ta wave in ST compared to the SR by calculating the new marker, i.e., the ratio of P-R_{ST}/P-R_{SR} and S-T_{ST}/S-T_{SR} to determine Ta wave peak location and amplitude exaggeration.

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2. Methodology

2.1. Study population

MLL was recorded for eight SR and fifteen ST volunteers (mean age of 24 years). Volunteers with a history of hypertension, chronic medications, or cardiovascular diseases were excluded. SR ECG was recorded in supine posture and volunteers after physical exercise achieving higher heart rate (≥ 100 bpm) were considered as ST. All the volunteers were informed about the study and participated with their consent.

2.2. Data acquisition

EDAN SE-1010 PC ECG system was used to record MLL frontal leads in SR and ST conditions at a standard paper speed of 25 mm/s and 10 mm/mV. Further, ECGs were magnified at 100 mm/s and 40 mm/mV for better resolution to reduce the inter and intra observer variability during parameters measurement. MLL II P-R and S-T segments amplitude were measured and analyzed.

2.3. Statistical analysis

P-R and S-T segment amplitude values were measured in mean ± SD. The data were checked for their normal distribution pattern by performing the Kolmogorov Smirnov test. Pearson's correlation, r value, was calculated to check the correlation between the amplitudes data. 2-tailed Student's T-test was used to determine the significant differences for unpaired data. $P < 0.1$ was considered as the level of significance.

3. Results

Mean ± SD values for P-R and S-T segment amplitudes were mentioned in Table 1. The impact of Ta wave was analyzed by determining the ratio of P-R segment amplitude in ST to SR. Similarly, the ratio of S-T segment amplitude in ST to SR. A 49.60 % increase in the negative amplitude was noted in $S\text{-}T_{ST}$ to $S\text{-}T_{SR}$ using absolute values of P-R and S-T, whereas a 41.60 % increase was noted in $P\text{-}R_{ST}$ to $P\text{-}R_{SR}$. Figure 1 shows ST ECG in MLL at standard paper speed. Further, the Ta wave peak can be predicted with the change in morphology and amplitude of the P-R and S-T segments at a paper speed of 100 mm/s and 40 mm/mV in Figure 2.

P-R segment % Increase = $\{(P\text{-}R_{ST} - P\text{-}R_{SR}) / P\text{-}R_{SR}\}*100$

S-T segment % Increase = $\{(S\text{-}T_{ST} - S\text{-}T_{SR}) / S\text{-}T_{SR}\}*100$

Table 1. P-R and S-T segment amplitudes in SR and ST

	Heart Rate (bpm)	P-R segment amplitude (μv)	S-T segment amplitude (μv)
SR	76 ± 11	22 ± 17	23 ± 14
ST	107 ± 7	31 ± 18	34 ± 12
% Increase		**$P\text{-}R_{ST}$ to $P\text{-}R_{SR}$**	**$S\text{-}T_{ST}$ to $S\text{-}T_{SR}$**
		41.60 %	49.60 %

4. Discussion

Ta wave, repolarization electric currents starting from the SA node and spreading in the right and left atria lead myocardial cells to achieve a resting state until depolarization currents. These currents represent Ta waves

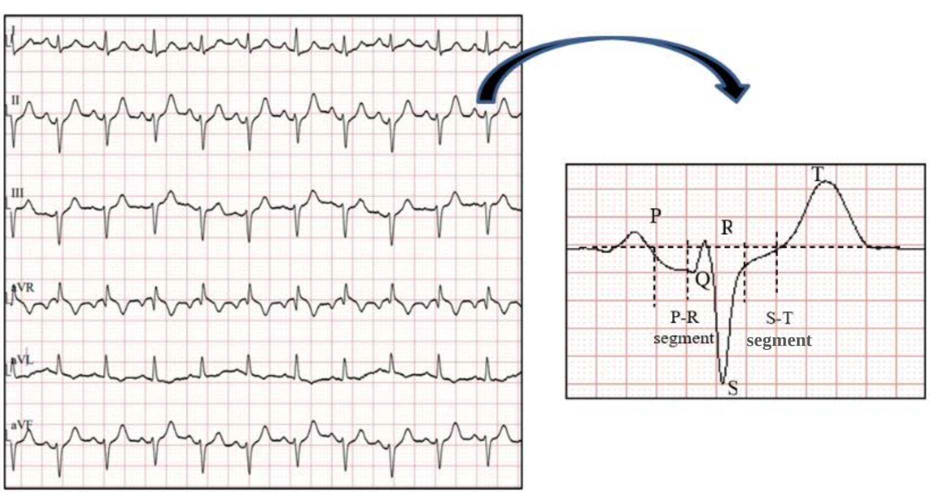

Figure 1. MLL frontal plane leads ECG of ST volunteer with the P-R and S-T segment depression due to Ta wave.

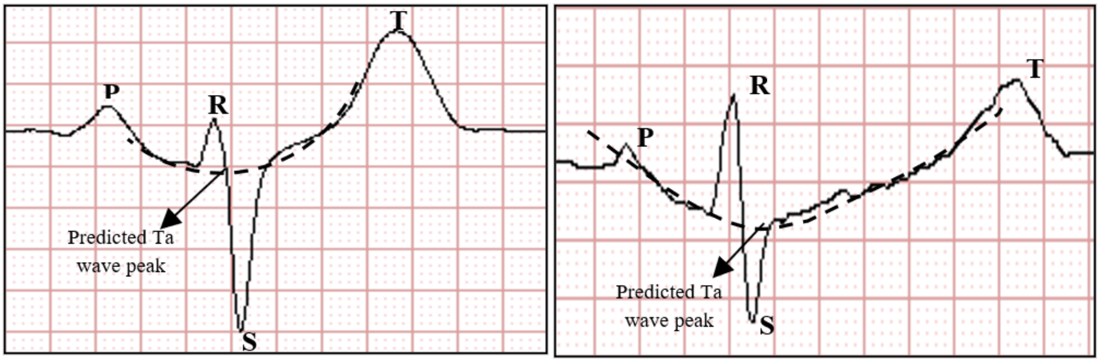

Figure 2. Ta wave peak location predicted by observing the morphology of P-R & S-T segment.

in an ECG signal. The presence of the QRS complex obscures the Ta wave in ECG signal. Therefore, a study [3] stated that a QRS-T cancellation algorithm is needed to visualize the Ta wave as a whole. The visualization and study of the Ta wave may be a potential marker for determination of cardiac diseases by studying their morphology characteristics in normal and diseased conditions. A study [5] stated that early Ta wave peak location can act as an indicator for arrhythmia. Therefore, it is timely to study its characteristics in detail. [8] studied the characteristics of Ta and P waves in the atrioventricular condition and determined that amplitudes change more compared to the change in duration parameters in disease conditions. Another study [10] determined that increased heart rate in ST condition leads to axis shift of the waves and the change in amplitude. Where the change in amplitude and heart rate is generally proportional. Ta wave peak amplitude can be predicted using the morphologies of the P-R and S-T segments; however, determining the Ta wave axis is an open area of research that needs to be studied.

The change in axis caused due to higher heart rate affects the ECG waves amplitude [11]. It was noted that change in ventricular repolarization (T wave) axis led to ventricular hypertrophy conditions. Therefore, T wave was marked as a potential indicator for various ventricular disorders [12,13]. Hence, similar results were noted in this study which signifies that at heart rate >100 bpm (arrhythmias of higher heart rate) may shift the Ta wave axis which increased the amplitude of Ta wave. Similarly, [14] noted that rapid heart rate encourages the Ta wave voltage to increase. Generally, the effect of Ta wave on S-T segment is low < 0.1 mm however in ST condition Ta wave depresses the S-T segment by > 0.1 mm. This may lead to misinterpretation and misdiagnosis of ECG as a myocardial ischemia [15]. Therefore, understanding of Ta wave characteristics in normal ECG signal and also at different heart conditions may provide the possibility for precise diagnosis in clinical ECG. Hence, deep insights in Ta wave and its morphology can be a potential marker for atrial arrhythmias and may also increase the true positive determination of myocardial infarction during retrograde atrial conduction.

5. Conclusion

This study helps determine the Ta wave peak location by analyzing sinus tachycardia volunteer’s PR and S-T segments. It may help delineate or predict atrial-related disease conditions by studying the recorded ECG language through its Ta wave characteristics. Moreover, a detailed study on S-T segment depression and elevation due to the Ta wave may help decrease the false-positive detection of myocardial infarction and ischemia.

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