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Research paper

ECG Measurements to Emphasize Atrial Potentials Using Modified Limb Lead System

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Abstract

With the advancement in the field of Electrocardiology (ECG), the acquisition of electrical activity of the heart plays an important role in the diagnosis of various cardiovascular diseases. In general, this activity of conduction is acquired using Standard 12 Lead ECG system. Recently, a Modified Limb Lead system has been developed to study the atrial electrical activity for the diagnosis of atrial arrhythmias. The present study is to derive the normal limits of female subjects using Modified Limb Lead (MLL) system. This study was evaluated in 59 female subjects 19.52 ± 1 (Mean ± S.D) and is primarily involved to study atrial potentials with the use of precordial and modified limb lead position. In sinus rhythm female subjects, the P wave amplitude was 33.06 ± 21.18 µV and the Ta wave amplitude was 20.72 ± 18.16 µV. The P wave duration was 94.22 ± 10.64 ms, the Ta wave duration was 85.51 ± 17.49 ms. The results show that modifications in the limb electrode placement have significant effect on amplitudes and PR segment which may be of great importance for the assessment of atrial potentials.

Index Terms: *Atrial arrhythmias, Electro cardiology, Modified Limb Lead System, Sinus rhythm, Standard 12 Lead System.*

1. Introduction

The standardized placement of limb lead electrodes to acquire the electrocardiogram of an individual was first introduced by Einthoven at al [1]. Where the next level of standardization of the limb leads is been proposed by Wilson et al [2] with the introduction of unipolar limb and the chest leads. Here the combination of electrodes led to the formation of 12 different types of leads (bipolar and unipolar limb leads, chest leads). Then the standardization of the chest (precordial) leads was performed by Barnes et al [3]. Whereas the placement of electrodes became difficult in the case of limb inapproachability so the newer system was proposed in which limb electrodes is been placed on the torso (chest) of an individual. bij Mason et al. [4] described this system for the exercise ECG for testing the stress condition and to avoid the movement artifacts. Then the idea of locating of the limb electrodes over the right side of the sternum was stated by Holzmann et al. [5] that the modification gives more atrial deflection in order to detect atrial fibrillation. This led to a study to visualize the Ta wave (atrial repolarization) which is been obscured by the simultaneous activation of ventricles and the repolarisation of the ventricles this concept is well described in Sivaraman et al. [6-10]. The reason behind it was reported by Jayaraman et al [11] i.e., in general the amplitude of the QRS complex (ventricular depolarization) is much greater than the Ta wave during the acquisition using standard 12 lead system, thereby this makes the Ta wave to hinder. Whereas in Sivaraman et al. [12, 13] reports that the great view of unmasked Ta wave is seen by the modification of bipolar limb lead to the right of the sternum. Then the later study of Jayaraman et al [14] proves that there is a major amplitude changes in the leads on comparison between MLL and SLL ECGs and also has an effect on wave amplitudes in the frontal axis whereas does not have any effect in the transverse axis since the precordial leads are left unchanged. The various alternative and special lead systems used in ECG recording are documented by Francis [15]. Madias [16] described ECG low voltage may have many causes, yet they can be classified by their generation (cardiac potential) and their influence over body (extra cardiac potential). Any significant abnormalities on the periphery may cause reversing of the QRS voltage, which in turn reduces amplitudes and time period of P and T wave, also their QT intervals, QRS complex and cause many consequences. Even alteration in heart's placement relative to the chest wall and Obesity are serious factors affecting the QRS complex. From the entire study there are many states affecting both healthy (normal) and abnormal subjects. Thus low cardiac volumes and decreased heart thickness and mass has significant effect on LQRSV which decreases amplitude and duration of P wave, T wave, QRS complex and even QT intervals. Macfarlane et al. [17] has described and created development of ECG database to distinguish the normal limits for South Asians (Dravidians) living in India. The system is mainly monitored and acquired using Standard 12 lead system. Increase and decrease of duration and amplitudes differ according to the origin and also the morphology taken into consideration. QTc is longer in females than upper limit in males. PR is larger in males and it also varies depending in age and gender. A normal distribution was performed using linear regression & t-test. Analysis clearly describes the range of normal limits to differentiate from the abnormality.

2. Methods

A. Subjects

Fifty nine healthy female subjects in the range of 18 to 21 years of age were included in this study. The distribution of mean age is 19.52 ± 1 (Mean ± SD). All healthy volunteers are from the Department of Biomedical Engineering in Vel Tech Multi Tech Dr.Rangarajan Dr.Sakunthala Engineering College, Avadi. Non-hypertensive subjects were included in this study. None of the subjects possessed any form of cardiovascular disorders. All the subjects gave consent for participation in this study.

B. Electrode Placement

The difference in limb electrode placement between standard 12 lead and modified limb lead system is described in table 1. The precordial leads remain same for both the lead systems. The surface electrodes are placed in supine position under resting condition. The principle behind ECG recording is when the depolarisation wave approaches the lead, it results in positive deflection and when it travels away from the lead, it results in negative deflection. The electrode placements are based on the cardiac vector axis.

The polarity of the modified limb electrode is same as Einthoven triangle [1, 6-9]. The modified limb electrode placement that forms the modified limb lead system is shown in figure 1. The difference in electrode placement between SLL and MLL system is shown in figure 2.

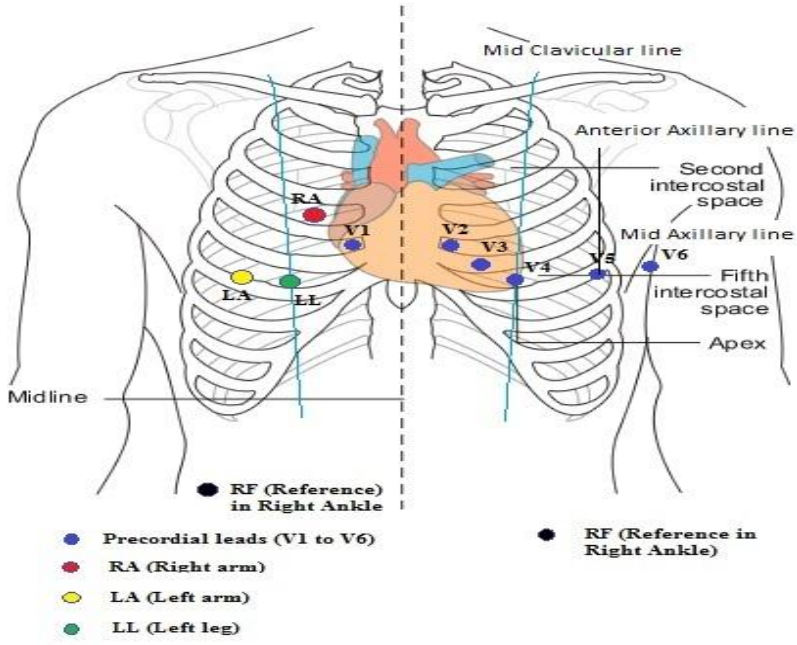

Fig. 1: Modified limb electrode placement

Table 1: Difference between SLL and MLL in ElectrodePlacement

Electrodes	Standard limb lead system	Modified limb lead system
Right Arm (RA) electrode	placed in the right arm between shoulder and wrist	placed on the 3rd right intercostal space, slightly left of the mid clavicular line
Left Arm (LA) electrode	placed in the left arm between shoulder and wrist	placed on the 5th right intercostal space, slightly right of the mid clavicular line
Right Leg (RL) electrode	placed in the right ankle (reference)	placed in the right ankle (reference)
Left Leg (LL) electrode	placed in the left ankle	placed on the 5th right intercostal space exactly in the mid clavicular line

C. Data Acquisition and Analysis

ECG samples are acquired in supine position using Standard 12 Lead and Modified Limb Lead system. Ag / AgCl surface electrodes for limbs and suction cup electrodes for chest are employed for the recording purpose. The acquisition is performed with the help of digital electrocardiograph (EDAN SE-1010 PC ECG system version 2.0, EDAN INSTRUMENTS, INC) operating at 1000 samples / second / channel with a frequency response of 0.05Hz to 150Hz (-3 dB). ECGs could be recorded at gain from 2.5mm/mV to 20mm/mV with a variable paper speed from 5mm/s to 50mm/s. In this study, the ECGs were recorded for 60 seconds each with paper speed of 25mm/s and gain of 10mm/mV. The records were then manually measured for comparative analysis.

In MLL ECG traces, the onset of P wave to the end of observable Ta wave is measured manually and is referred to as P-Ta interval [8]. The end of P wave to the end of observable Ta wave is known as Ta duration.

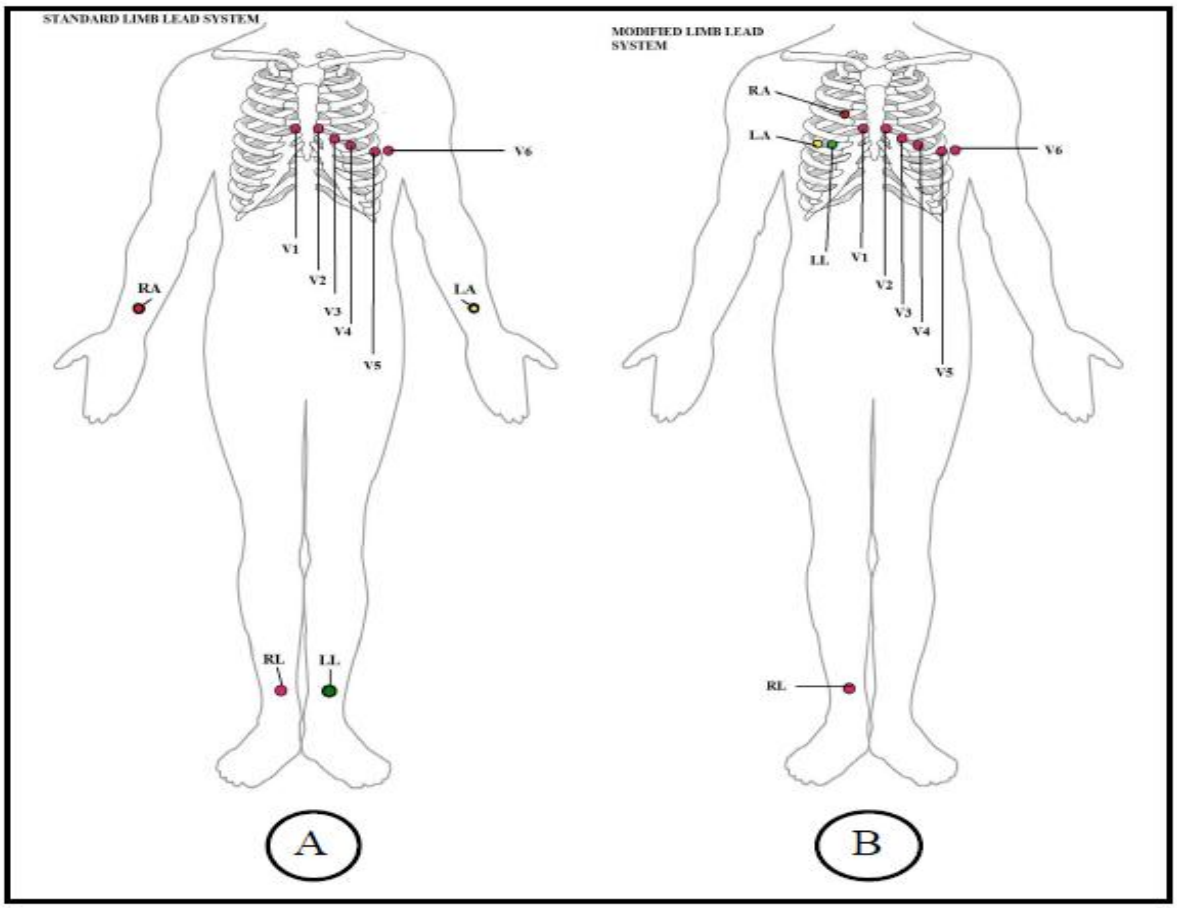

Fig. 2: Difference in electrode placement between SLL & MLL system
(A - denotes the Standard Limb Lead Placement ; B - denotes the Modified Limb Lead Placement)

D. Statistical Analysis

The ECG traces are statistically analyzed using WinStat in Excel for Windows office 2007. The measurements such as amplitude and time duration are expressed in terms of Mean ± Standard deviation. The student t-test was performed to return the probability value for dependent and independent variables. It determines the extent at which the differences are significant (low P value). All the values are one sided with $p<0.5$ were found to be statistically significant.

3. Results

The standard and modified limb lead ECGs were recorded at standard paper speed of 25mm/s with gain 10mm/mV in supine position for healthy female subjects. The standard 12 lead ECG of a female subject recorded at standard paper speed using EDAN PC ECG system is shown in figure 3.
In standard 12 lead ECG traces, the amplitude of P wave is much smaller and the PR segment is an iso-electric line in all the leads. The R wave amplitude is higher in all the leads. The presence of atrial repolarisation (Ta wave) remains obscure in QRS complex when recorded in standard limb lead (SLL) system [7,8]. The MLL ECG of the same female subject recorded using EDAN PC ECG system is shown in figure 4.

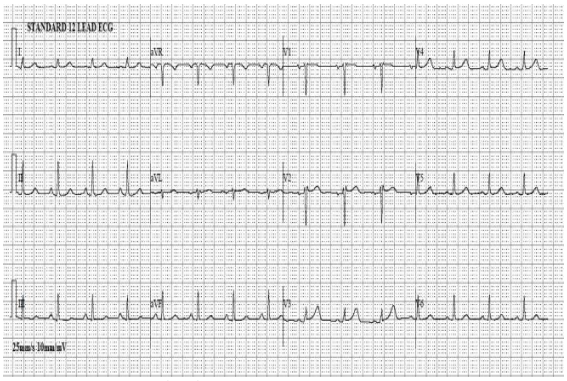

Fig. 3: Sinus rhythm of a female (20 yrs old) subject recorded at 25mm/s and 10mm/mV using Standard Limb Lead system (SLL)

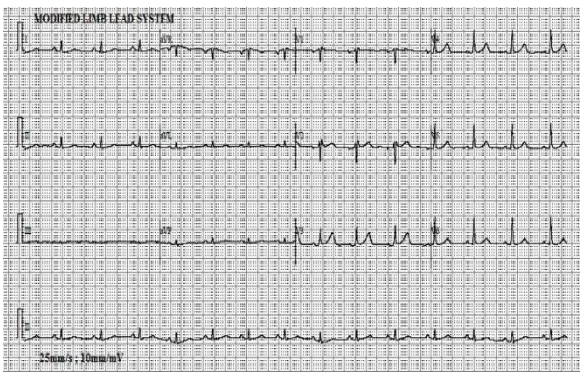

Fig. 4: Sinus rhythm of a female (20 yrs old) subject recorded at 25mm/s and 10mm/mV using Modified Limb Lead system (MLL), which clearly shows the presence of atrial Ta wave

Due to the modifications in the limb lead positions, the observable P wave has greater amplitude than SLL. The MLL ECG traces

have shown significant changes in R wave amplitude and PR segment. The Ta wave is clearly noticeable in the non iso-electric PR segment in all MLL ECG traces except MLL III. This non iso-electric line is represented as Ta wave [7-10].

In modified lead aVR, the Ta wave is seen as a positive potential and negative in all the other leads as shown in figure 4. Generally, lead aVR tends to possess negative P wave when recorded in SLL system. The same is reflected in MLL aVR in agreement with aVR = -I - III/2 [1]. There exists opposite polarity between P wave and Ta wave. The left arm (LA) and left leg (LL) electrodes are positioned nearer to each other. Hence, in most of the MLL ECG traces it has shown flat response in modified lead III. Yet, few of the traces revealed significant lower amplitude R wave with no distinct P and T wave in modified lead III. As the electrodes (V1 to V6) placed in the transverse axis are left unchanged during recording with modified lead positions, there is no significant change in the amplitudes of P, Q, R, S and T waves. The amplitudes of P wave and Ta wave of 59 sinus rhythm female subjects are shown in Table 2. The values are represented in terms of mean ± standard deviation.

Table 2: P Wave and Ta Wave Amplitudes (µV) in 38 Sinus Rhythm Female Subjects

Measurement	Lead	Modified limb position (MLL)	
		Sinus rhythm subjects n=59	
		MEAN	SD
P wave amplitude	I	80.68	26.02
	II	84.84	25.41
	aVR	-81.68	26.42
	aVL	38.18	14.19
	aVF	43.31	13.86
Ta wave amplitude	I	-45.5	20.55
	II	-48.97	20.08
	aVR	43.15	20.21
	aVL	-22.5	14.73
	aVF	-29.84	15.06

MLL - Modified limb lead, SD - Standard deviation, All the values are in micro volt (µV)

The amplitude values of P wave and Ta wave are statistically analyzed and a correlation was obtained. The values were found to be statistically significant ($p<0.5$). All the values are one - sided in Pearson correlation with $r = 0.03$ to 0.12 and $p<0.5$. Although the correlation is positively correlated, the relationship between P wave & Ta wave is very weak (nearer the value to zero, weaker the relationship). The value of coefficient of determination $R^2 = 0.0009$ to 0.0144.

As Ta wave is observable in the PR segment, there is a significant change in the duration of P wave and Ta wave. The duration of Ta wave starts from the end of P wave and extends to the onset of R wave. The duration details for P wave and Ta wave are elucidated in the Table 3. The durations of P wave, Ta wave, P-Ta interval and corrected P-Ta interval of the MLL ECG traces were found to be statistically significant with $p<0.5$. The plot of mean ± SE of P wave and Ta wave duration acquired using modified limb lead system is shown in figure 5.

4. Discussion

A. Impact of Modified Limb Electrode Placement

The modified limb electrodes are placed according to the spread of atrial depolarization and repolarization wavefronts from the SA node with respect to the mean electrical vector axis of atrial depolarization and ventricular depolarization [6,13]. The conduction and propagation of electrical impulse takes place parallel to the atrial muscular wall. As the cardiac vector axis varies for every individual, distinct Ta wave is noticeable only for subjects with P wave axis in the range between 27 and 90° which is in agreement with Sivaraman et al [6]. For all the other individuals, a normal ECG waveform is obtained when recorded with the modified limb position.

B. Impact of Atrial Repolarisation (Ta wave) in PR Interval

The modifications in limb lead position produced significant effect on the PR segment. In MLL ECGs, the PR segment is non iso-electric with saucer like depression in leads I and II. This depression in PR segment is termed as Ta wave as proposed in previous studies Jayaraman et al [8-10]. Subjects with low QRS voltage [16] in leads I and II when recorded in SLL system tends to posses amplitude changes in MLL system. Hence, Ta wave is clearly recognized when recorded with modified limb position. Low voltage QRS is observed in subjects who are physically lean and obese Madias [16]. In SLL ECG traces, the atrial repolarisation (Ta wave) remains obscure due to simultaneous activation of the ventricles. In general, Ta wave is superimposed onto the QRS complex and ST segment. The Ta wave and P wave are in opposite polarity which is in agreement with Jayaraman et al [8]. The end of P wave to the end of observable Ta wave is denoted as the "Ta duration". There are considerable difficulties in measuring Ta wave amplitude and Ta wave duration.

C. Impact of Ta Wave

In about 59 healthy female volunteers are included in this study, only 38 individuals are noticeable with Ta wave.

Table 3: P wave and Ta wave durations (ms) in sinus rhythm female subjects recorded with modified limb lead system

Measurement	Modified limb lead	Sinus rhythm subjects n= 59	
		Mean	SD
P wave duration	I	94.23	11.1
	II	96.26	10.05
	aVR	94.92	10.07
	aVL	92.05	12.08
	aVF	93.68	9.93
Ta wave duration	I	89.13	17.87
	II	87.76	14.91
	aVR	84.86	14.99
	aVL	85.47	18.63
	aVF	80.34	21.08

MLL - Modified limb lead, SD - Standard deviation,
All the values are in milli seconds (ms)

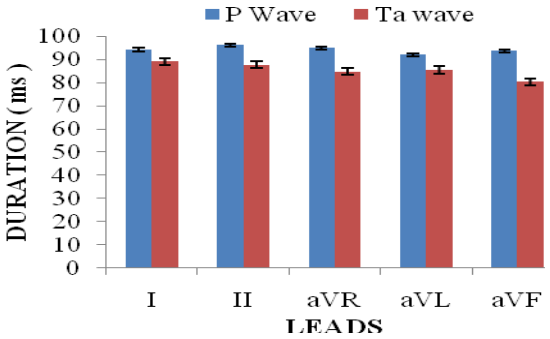

Fig. 5: Plot of mean ± SE of P wave and Ta wave duration acquired using modified limb lead system

5. Study Limitations

The study includes only a mere group of female volunteers aged between 18 to 21 years. The results are feasible for resting, supine healthy female subjects. The study doesnot include participation of male subjects. The precise distribution of cardiac vector for female subjects has to be considered and an alternative lead system may be proposed.

6. Conclusion

The standard 12 lead ECG system has limitations in the detection of atrial potentials. Hence, the modification of limb leads are adopted to produce significant changes in atrial potentials (amplitude and duration) compared to standard limb lead system. This modification focusses on atrial depolarization and repolarization waves which plays a key role in early detection of atrial arrhythmias

7. Acknowledgment

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