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A Deterministic Approach for Finding the *T* Onset Parameter of Flatten *T* Wave in ECG

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Identification of the exact nature of flatten *T* wave in ECG signal is Classification of normal and abnormal *T* wave episodes especially, regarding Flatten *T* wave in electrocardiography (ECG) signal is still a complex phenomenon for cardiologists. Identification of Flatten *T* wave depends on four parameters; Time duration (T_{dur}), *T* onset (T_{on}), *T* offset (T_{off}) and *T* peak (T_{pk}) values which play a vital role to identify the exact nature of Flatten *T* wave. The proposed approach is used to extract the T_{on} value of Flatten *T* wave with the detection of *R* peaks and RR intervals. The proposed approach is applied to ten different subjects of Flatten. It is divided into three distinct phases. Firstly, Flatten signals are segmented by lead wise. Secondly, noise filtration is done to identify the peak values and removal of low-frequency components. A third phase computes the *R* peak values and RR intervals with the help proposed algorithm. By using the *R* peak value as a fiducial point and considering the last interval of RR interval instead of complete *T* wave alternans detection algorithm (TWA) for determination the T_{on} parameter of Flatten *T* wave. The experimental evaluation manifests that efficiency factors are high in rate during the operational investigations (closest to the range of 100%). These efficiency factors have been discussed in the context of accuracy, sensitivity, prediction and error rate. These operation efficiency factors will play a benchmark role in future for calculation the others parameters of Flatten *T* wave.

Keywords: myocardial infarction, flatten *T* wave, *R* peak detection, electrocardiography, wavelet analysis

1. INTRODUCTION

Advancement in technology has always been a game changer in different real-time medical diagnostics such as MRI, X-Ray films, various blood tests and ECG *etc.* In particular, researches related to heart diseases always gain a special attention for medical professionals due to false alarm detection of cardiovascular diseases (CVDs) in ECG. The ratio of human deaths in nowadays is continuously increasing due to these CVDs and the main reason for these diseases is due to unhealthy lifestyle [1]. In particular case

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of accurate detection of myocardial infarction (MI) helps the physician to deliver the invaluable and timely treatment to patients. There are still some worst situations like MI abnormalities which exist in electrical activities of heart which can be monitored in ECG. ECG works for monitoring the electrical activities of human hearts by using the 5 to 12 electrodes which are attached to different areas of human body. ECG signal is broken into segments such are P wave, QRS complex, ST segment and T wave [1]. Each segment represents different kinds of heart activities [2]. There are some abnormalities which exist in heart's electrical activities like ST-segment elevation MI (STEMI), non-ST segment elevation/depression MI (NSTEMI), T wave inversion and Flatten anomalies of ST segment and T wave [3]. Flatten anomalies of ST segment and T wave in ECG signal are still an open myth for physicians and cardiologists [4]. In diagnostic purposes of MI affected patient requires special attention. Such diagnostic purposes are only possible by performing better and accurate classification between normal and abnormalities T wave especially correct identification of Flatten T wave. Classification of these Flatten anomalies is performed by a parametric solution. Such parametric solution urges to deliver the better classification results regarding high accuracy and sensitivity along with minimal error rate.

According to literature, the parametric solution is the best method for classification the ECG abnormalities. Analysis of beat-to-beat, heart rate variability, detection of atrial fibrillation (AF), detection of premature ventricular contraction (PVC) and detection of myocardial infarction (MI) are dependent on such parametric solutions [5, 6]. Parameters like amplitude, start time, end time and time duration of different ECG features always become handy for the diagnostic purpose of various diseases. This research article delivers the deterministic approach for finding the T_{on} parameter of Flatten T wave which is helpful in recovery of a patient at a particular stage. According to this research, firstly segmented the ECG signals and then apply the filtration process on the signals for removal of unnecessary components in the signal. In detection phase of R peaks values and RR intervals identification the accurate number of R peaks along with RR intervals by using our proposed algorithm. Next step is an integration phase, our findings regarding detected R peak values and RR intervals are embedded in a key part of the TWA algorithm which is the state-of-the-art work. By execution of these two phases on ten different subjects of Flatten T wave and discern the T_{on} parameter of Flatten T wave. By using our best knowledge, previously no one works on the parameters of Flatten T wave and nature identification of Flatten T wave with the help of is still a pending job. So far we are the first one for giving the solution of a T_{on} parameter of Flatten T wave. Such solution is a baseline for opening the new debate regarding finding the exact nature of Flatten T wave. With the help of our solution in future, we will highlight the other parameters like T_{dur}, T_{off}, and T_{pk} values. Combination of these T wave parameters will be a complete package for exact nature determination of Flatten T wave. Operational investigations of T wave concerning the parametric solution are also helpful for other analysis like the beat to beat analysis, heart rate variability (HRV) and ST segment analysis of MI. A summary of our contributions is followed in below for further observations.

- Initializing step for identifying the exact nature of Flatten T wave in the context of T_{on} parameter.
- Derivation of T_{on} parameter in this approach reflects the involvement of external de-

pendencies factor in ECG features. Such solution works under usage the state-of-the-art TWA detection algorithm.
- After the operational investigations, deliverables regarding efficiency factors are approx. 100%.

1.1 Abbreviations and Acronyms

Abbreviations and acronyms are highlighted in Tables 1 and 2.

Table 1. Abbreviation section.

Abbreviations	Description
ECG	Electrocardiography
MI	Myocardial infarction
STEMI	ST Segment elevation myocardial infarction
NSTEMI	Non ST Segment elevation myocardial infarction
WTMM	Wavelet Transform Modulus Maxima
PVC	Premature Ventricular Contraction
AF	Atrial fibrillation
HRV	Heart Rate Variability
CVDS	Cardiovascular diseases
TRA	Trapezium's area

Table 2. Acronyms with description.

Acronyms	Description
T_{dur}	Time duration of *T* wave
T_{amp}	Amplitude value of *T* wave
T_{on}	*T*-onset parameter of Flatten *T* wave
RAD	Ration of accurate detection
S_e	Sensitivity
E	Error ratio or Error rate
TP	True positive *R* peak detection
FP	False positive *R* peak detection
Fn	False negative *R* peak detection

Rest of this research article will discuss the previous analysis of ECG along with the related *R* peak analysis in section 2. Section 3 discusses the systematic methodology of our proposed approach. Section 4 shows the algorithmic flow of our approach. Section 5 will be the result, and section 6 deals with discussion part of our findings regarding accuracy, sensitivity, prediction and error ratio in our approach. Section viii highlight the conclusion and future directions of the article.

2. LITERATURE SURVEY

In ECG signal each segment and duration of each segment have some information, such information can be easily understandable by cardiologists. In the normal routine, 12-leads are used for measuring the electrical activities of the human heart. For reducing the computational complexity, five lead ECG is used instead of 12 lead ECG [7]. Parameters of 5-lead ECG are (RA) right arm, (RL) right leg, (LA) left arm (LL) left leg and septal lead V1 or lead V5 typically chosen for analyzing of the five lead signals. Each electrode on human body captures heart's electrical activity from different angles. These angles are represented in the form of different wavelet segments. These segments are represented as a P wave, ST segment, QRS complex and *T* wave on ECG Wavelet. The most significant segment in ECG is *T* wave, which indicates the repolarization of ventricular [8]. Such repolarization of ventricular indicates the healthy or unhealthy status of the heart. In particular MI case, Flatten ST segment and Flatten *T* wave are hot issues for cardiologist experts [9, 10].

Robotic detection of the ST segment and *T* wave changes may cause the survival of human life. Normally we can skip the minor detail in heart analysis like the intensity of MI, which means changes regarding amplitude and time duration of ST segment and *T* wave. One approach is trapezium's area (TRA) approach which works to locate the *T* peak through the maxima and minima value by using the window based method. In TRA method, three vertex's are fixed and one is mobile which is shifted over the ECG signal [11].

TRA approach is a handy tool for detection of *T* wave in ECG signal with the presence of different noise factor. one of the drawbacks in this method actually works only for the detection of biphasic *T* wave whereas, identification of the time duration (T_{dur}) and amplitude of Flatten *T* wave is still an open job. Literature reflects the parametric importance of ECG features regarding classification and identification. Despite for understanding the ECG feature parametric importance which reveals equally in each feature. Parametric discussion of *T* wave always surround over the four parameters such are *T* onset, *T* offset, T_{dur} and *T* amp which is highlighted in Table 3.

Table 3. Key parameters of *T* wave in ECG.

Different *T* Wave Parameters	
Parameters	Description
T_{onset}	Start time of the *T* wave in ECG
T_{offset}	End time of the *T* wave in ECG
T_{amp}	Peak value between *T* onset and *T* offset
T_{dur}	*T* wave duration between *T* onset and *T* offset

Table 4. Standard readings of ECG features [12].

Peak Values	Amplitude	Intervals	Duration
P-Wave	0.75mV	P_R Interval	0.12 to 0.20 Sec
R-Wave	1.60mV	QT Interval	0.35 to 0.49 Sec
Q-Wave	25% of R-Wave	ST Segment	0.05 to 0.15 Sec
T-Wave	0.1 to 0.5mV	P wave Interval	0.11 Sec
		QRS Complex	0.09 Sec
		PR Segment	0.06 to 0.15 Sec
		T wave	Varies

Table 4 highlights the baseline readings of different feature parts of ECG; such baseline readings play a vital role for any parametric derivation [12]. The scope of this article clears to highlight the parametric solution of Flatten *T* wave regarding T_{on} Parameter. Determination the exact nature of Flatten *T* wave is only possible by adopting the parametric solution, but unfortunately, no standard baseline values for *T* wave parameters exist in literature, so comparison of derived results with any standard or baseline values is not possible [13, 14]. Nature marking of Flatten *T* wave is an unconceivable task in such circumstances. Under such situation in this research, we have adopted the novel base state-of-the-art solution for the derivation of T_{on} by finding detection of *R* peaks and RR intervals [15, 16]. To diagnose different cardiac disease we normally use the ECG signal analysis with various approaches. One of them is a beat-to-beat analysis which deals with QT interval, the time interval between Q wave onset (start time of Q wave) and *T* wave offset (end time of *T* wave) [17, 18]. Another approach is mathematical modeling which is applied on ECG signal for calculations the time duration and amplitude of different segments like ST segment, QT interval, RR interval and *T* wave. Similarly, wavelet analysis integrates Wavelet Transform Modulus Maxima (WTMM). WTMM represents the characteristic behaviors of heart signals in ECG and is a part of *T* wave detection algorithm which works with the combination of wavelet transforms regarding amplitude and slope of *T* wave [19-21].

3. SYSTEMATIC METHODOLOGY

In the context of drilling towards the solution of the problem, finding the T_{on} parameter of Flatten *T* wave by considering the ten different subjects of Flatten *T* wave. Such finding is a first step towards highlighting the nature of Flatten *T* wave. Below showcase in Fig. 1 highlights the system model in the form of a block diagram. Such system model is a representation of proposed approach towards marking the T_{on} parameter of Flatten *T* wave under usage of *R* peak analysis and then state-of-the-art TWA detection algorithm by considering the *R* peak as a fiducial point. Below Eq. (1) is a core part of our approach that is adopted from TWA detection algorithm [15, 16].

$$T_{on} = 40 + 1.33\sqrt{RR_i} \tag{1}$$

According to the flow of model, the segmentation process is applied to ten different subjects of ECG data (Flatten *T* wave) which splits data into lead wise, lead II and lead III.

The onwards implication the noise filtration by using the high-pass filter for removal of low-frequency components and dominate the peak values.

These highlighted peak values are further investigated by a proposed algorithm which deals with the detected *R* peak values along with the RR intervals. The second part of the algorithm sets the threshold values for measurement the operational efficiency. These threshold values work for accuracy calculation regarding the ratio of accurate detection (*RAD*) of *R* peaks, Sensitivity (S_e), Positive prediction index (P_+) of T_{on} by detected *R* peaks and error rate calculation (*E*). After the execution of the algorithm, at the final step of the proposed approach is taking the *R* peak as the fiducial point and insert the final derived value of RR interval (RR_i) in Eq. (1)

In the context of operational efficiency of this approach, threshold values are the key builder points. Three threshold levels of *R* peaks are detected and assigned ranges. True positive detected *R* peak (*TP*) set a range values th1 = 0.3mV to 0.4mV, false positive detected *R* peak (*FP*) range is th2 = 5.1mV to 5.2mV, and finally false negative detected *R* peak (*FN*) under the range of th3 = 0.04mV to 0.1mV. Usage of below equations regarding measurement the operational efficiency of our approach under the umbrella of these threshold values

$$S_e = \frac{TP}{TP+FN} * 100, \tag{2}$$

$$Sum = TP + FP + FN,$$

$$RAD = \frac{TP}{Sum} * 100, \tag{3}$$

$$P_+ = \frac{TP}{TP+FP} * 100, \tag{4}$$

$$E = \frac{FP+FN}{TP+FN} * 100. \tag{5}$$

These above from Eqs. (2)-(5) works for the derivation of sensitivity, the ratio of accurate detection, positive prediction index and error rate or ratio.

Derivation of these operational factors for tracing the T_{on} parameter of Flatten *T* wave that totally depends on the detected *R* peak values. Such derivation clearly, imposes the involvement of dependencies factor of ECG features. Reflection of this above discussion regarding proceeding this efficient approach. Such efficient approach uses ten different subjects of UMMC (University of Malaya Medical Center) dataset which have to Flatten *T*. Highlight the average value of T_{on} of Flatten *T* wave with the help of analysis the T_{on} values of ten different subjects by using such approach. The first stage detects the number of *R* peaks in the filtered segmented signal of ECG with the help of window filtration. Whereas, the second stage highlights the maximum RR intervals and the next stage is using the methodology of TWA detection algorithm by considering the last RR interval. Such RR interval embeds on Eq. (1) for the derivation of T_{on} value. The implication of these two stages on both leads work for comparative analysis, with the help of such analysis further qualitative improvement will also be possible. Before proceeding to simulation work, adjust the setup of different parameters. Table 5 highlights the complete package of simulation setting before proceeding to operational activities.

Table 5. Simulation setting before proceeding the operational work.

Sr #	Flatten *T* record M_tag	Lead wise Segmentation	Signal Sample	Window size(W)	*R* peak Threshold values (mV)		
					th1	*th2*	*th3*
1					0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
2	me09154	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
3	me09426	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
4	me09470	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
5	me09824	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1

Table 5. (Cont'd) Simulation setting before proceeding the operational work.

Sr #	Flatten *T* record M_tag	Lead wise Segmentation	Signal Sample	Window size (W)	*R* peak Threshold values (mV)		
					th1	*th2*	*th3*
6	me09847	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
7	me09934	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3to 0.4	5.1 to 5.2	0.04 to 0.1
8	me10002	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
9	me10233	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
10	me10235	lead II	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1
		lead III	1000	300	0.3 to 0.4	5.1 to 5.2	0.04 to 0.1

4. ALGORITHMIC STRUCTURE

Coverage of algorithmic structure of proposed approach is a joint venture of few structural components. Under the usage of these components, this approach works and delivers the T_{on} parameter of Flatten *T* wave. Core or heart part of the approach is taking *R* peak as a fiducial point that already discussed in above methodology section. Before proceeding towards simulation work, firstly discuss the key builders of the proposed algorithm. These key builder points are already markup in Fig. 1 that represents the system model of proposed approach.

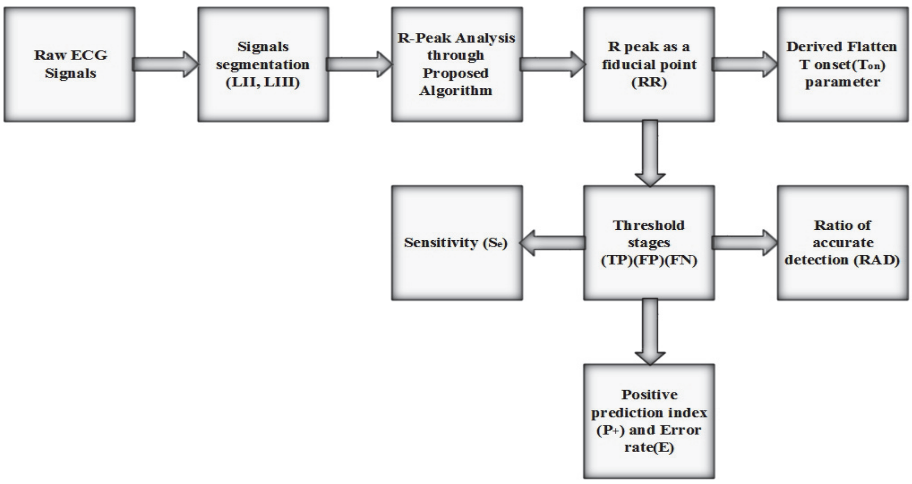

Fig. 1. Representation of system model for highlighting the (T_{on}) of Flatten *T* wave.

4.1 Segmentation

Consider the ten different subjects of Flatten *T* wave which are recorded by task force monitor. In taskforce, monitor machine leads II and lead III is perfect for analysis of the ECG due to maximum features extracted. The first step of our algorithmic modeling is to pick the raw ECG signals one by one in a subject manner and then segmented the signals by lead II and lead III by using manual splitter technique.

4.2 *R*-Peak Analysis

Such component works after the noise filtration of low-frequency components of ECG signal, *R*-Peaks value is identified by locating the *R* peak, compute and store the located *R* peaks. To determine the maximum amplitude of *R* peak these detected numbers of *R* peaks are used the sort function of Matlab.

4.3 Noise Filtration

At this phase, take the segmented signals by a lead wise and use high pass filter for removal of low-frequency components in the ECG signals. With the help of high-pass filter identify the *R* peak very easily by using the window filtration technique in *R* peak analysis phase. Eq. (6) represents the filtration method for removal of different low-frequency components and 1000 is a sampling rate of the ECG signal.

$$H = (1000,\ 1/1000*2.\text{'High'}) \tag{6}$$

Above structure of the algorithm indicates that solution of T_{on} parameter of Flatten *T* wave relies on the accurate detection of *R* peaks and RR intervals. Such algorithm breaks into two core parts that are detection process of *R* peaks along with last RR interval, then mark the positive and negative *R* peaks for measuring the accuracy, sensitivity, positive prediction index and error rate. According to system modeling, the structure of proposed algorithm is map up with the model. The first phase of the algorithm reflects segmentation process in which raw data of ECG breaks into leads wise (lead II and lead III). Next step implication of high-pass filtration for removal of low-frequency components and highlight the values of *R* peak. After onwards normalize the lead wise ECG signal and then locate the *R* peak values (R_Loc). These *R* peaks location is computed and store (pk_R) for further operational investigations. To determine the operational efficiency of such approach by using the window filtration (size of window W = 300). Along with window filtration, sets the three threshold values which already discussed in system modeling section

5. RESULT

Identifying the T_{on} parameter of Flatten *T* wave is the first step towards highlighting the exact nature of Flatten *T* wave. In this deterministic approach raw signals are segmented into lead wise (lead II and lead III for maximum feature extraction) and then apply high pass filter for removal of low-frequency components in the signal by setting the Frequency generation fs = 1000. After the removal of low-frequency components then set the three threshold values (th1 = 0.3mV to 0.4mV, th2 = 5.1mV to 5.2mV and th3 = 0.04mV to 0.1mV) for determining the true positive number of *R* peaks (TP),false positive number of *R* peaks (FP) and false negative number of *R* peaks (FN). Implementation of this efficient approach on ten different M_Tag_patient records which have Flatten *T* wave and summarized the results of T_{on} values, number of detected *R* peaks and last part of the RR interval (RR_i) in Table 6. Showcase of three threshold values, sensitivity, ratio of accurate detection, positive prediction index and error rate highlight in Table 7. Next step is to highlight the mean values of T_{on} values, sensitivity, and the ratio of accurate detection, positive prediction index and error rate of lead II and lead III by findings in Table 7. With the help of these tables, comparative analysis between both leads is a quite simple job and productive one in terms of future improvement.

Table 6. Findings of different parameters of ten subjects (mTag_patients) of UMMC dataset.

Sr #	M_Tag_ patients	Segmen-tation	*T*-onset (milli sec)	*T*-onset (sec)	Detected *R* peaks	Detected RR interval	RR_i
1	me10233	LII	40.33	0.04033	345	344	0.062
		LIII	40.36	0.04036	2836	2835	0.075
2	me10235	LII	40.35	0.04035	144	143	0.070
		LIII	41.16	0.04116	349	348	0.764
3	me10236	LII	40.61	0.04061	44	43	0.923
		LIII	41.27	0.0412	222	221	0.213
4	me09426	LII	40.34	0.04034	235	234	0.053
		LIII	40.3	0.0403	3455	3454	0.069
5	me1002	LII	40.47	0.0407	362	361	0.126
		LIII	40.47	0.0407	362	361	0.126
6	me09934	LII	41.14	0.04114	65	64	0.121
		LIII	40.46	0.04046	379	378	0.739
7	me09847	LII	40.37	0.04037	245	244	0.05
		LIII	40.29	0.04029	3012	3011	0.081
8	me09824	LII	40.3	0.0403	339	338	0.098
		LIII	40.41	0.04041	1632	1631	0.052
9	me09154	LII	40.34	0.0403	187	186	0.095
		LIII	40.4	0.0404	2773	2772	0.066
10	me09470	LII	40.45	0.0404	220	219	0.983
		LIII	40.31	0.041	232	231	0.118

5.1 LEAD II Values

Let's consider the lead II for deriving mean value T_{on} of Flatten *T* wave in terms of milliseconds and seconds. *N* represents the ten different subjects of Flatten *T* wave ($N = 10$) in Eqs. (7)-(11).

$$\text{Lead II } T\,(T_{on}) = 1/N \sum_{i=1}^{N} T_{on}^{\,i} \tag{7}$$

Usage the results of Table 7, Eq. (7) is implemented on T_{on} values of lead II. Get the result in the context of milliseconds and seconds, lead II $T(T_{on})$ = 43.73 ms and lead II T (T_{on}) = 0.04497 sec. The Same methodology is executed on Sensitivity (S_e), Ratio of Accurate Detection (*RAD*), Positive prediction index (P_+) and Error rate (*E*) by using the results of Table 7.

Table 7. Representation of factors Sensitivity (S_e), Ratio of accurate detection (RAD), Positive prediction index I (P_+), Error Rate (E).

Sr #	M_Tag_ patients	Segmen-tation	*TP*	*FP*	*FN*	S_e (%)	*RAD* (%)	(P_+) (%)	*E* (%)
1	me10233	LII	344	0	1	99.42	99.42	100	0.57
		LIII	2835	0	10	99.64	99.64	100	0.35
2	me10235	LII	143	0	1	99.3	99.3	100	2.2
		LIII	348	0	2	99.42	99.42	100	0.57
3	me10236	LII	43	0	1	97.72	97.72	100	2.2
		LIII	221	0	10	99.54	99.54	100	0.45
4	me09426	LII	234	0	1	99.57	99.57	100	0.42
		LIII	3454	0	12	99.65	99.65	100	0.34
5	me1002	LII	361	0	2	99.44	99.44	100	0.55
		LIII	361	0	2	99.44	99.44	100	0.55
6	me09934	LII	64	0	1	99.46	98.46	100	1.53
		LIII	378	0	2	99.47	99.47	100	0.52
7	me09847	LII	244	0	1	99.59	99.59	100	0.408
		LIII	3011	0	11	99.63	99.63	100	0.36
8	me09824	LII	338	0	2	99.41	99.41	100	0.58
		LIII	1631	0	6	99.63	99.63	100	0.36
9	me09154	LII	186	0	1	99.46	99.46	100	0.53
		LIII	2772	0	10	99.64	99.64	100	0.35
10	me09470	LII	219	0	1	99.55	96.55	100	0.45
		LIII	231	0	1	99.56	99.56	100	0.43

$$\text{Lead II } (S_e) = 1/N\sum_{i=1}^{N} S_e^i \tag{8}$$

Eq. (8) represents the summation of ten sensitivity values

$$\text{Lead II } (RAD) = 1/N\sum_{i=1}^{N} \tau^i. \tag{9}$$

In Eq. (9) τ represents the mean ratio of accurate detection (*RAD*) of ten Flatten subjects

$$\text{Lead II } (P_+) = 1/N\sum_{i=1}^{N} p_+^i. \tag{10}$$

Derivation the mean value of the positive prediction index in Eq. (10)

$$\text{Lead II } (E) = 1/N\sum_{i=1}^{N} \eta^i. \tag{11}$$

Showcase of error ratio in Eq. (11) represents in the form of η.

Extracted mean values from Eq. (8) to (11) are Sensitivity(S_e) = 99.29%, Ratio Accurate Detection (*RAD*) = 99.29%, Positive Prediction Index (P_+) = 100% and Error rate (*E*) = 0.74%.

5.2 LEAD III Values

The Same scenario is applied on lead III values as applied to finding the lead II values. At first, finds the mean value of Flatten *T* wave T_{on}. Like lead II, *N* represents ten subjects of Flatten *T* wave from Eqs. (12)-(16)

$$\text{Lead III } T(T_{on}) = 1/N \sum_{i=1}^{N} T_{on}^{\,i}. \tag{12}$$

By using Eq. (12) we get the value Lead III $T(T_{on})$ = 40.54ms, Lead III $T(T_{on})$ = 0.0406 sec. Extraction the efficiency factors of lead III are getting on sane way like the lead II, get the mean value of Sensitivity (S_e), Ration accurate detection (*RAD*), Positive prediction index (P_+) and Error rate (*E*) by using below equations

$$\text{Lead III } (S_e) = 1/N \sum_{i=1}^{N} S_e^i. \tag{13}$$

Above Eq. (13) highlights lead III to mean value of ten different subjects of Flatten *T* under the factor of sensitivity

$$\text{Lead III } (P_+) = 1/N \sum_{i=1}^{N} p_+^i. \tag{15}$$

Indication of Eq. (15) is the lead III mean value of positive prediction index of ten different Flatten *T* subjects

$$\text{Lead III } (E) = 1/N \sum_{i=1}^{N} \eta^i. \tag{16}$$

Error ratio in Eq. (16) represents in the form of η.

Mean values of Sensitivity (S_e), Ratio Accurate Detection (*RAD*), Positive Prediction index (P_+) and Error rate (*E*) are of Lead III are S_e = 99.56%, *RAD* = 99.56%, (P_+) = 100% and *E* = 0.428.

6. DISCUSSION

6.1 Comparative Analysis of Lead II and Lead III

Derivation of Mean values of parameter T_{on} and operation efficiency factors are highlighted in Table 8 for comparative analysis. Fig. 2 is a graphical representation of comparative summary that plays a vital role for further investigation regarding qualitative improvement in this approach. Fig. 2 reflects that lead II and lead III both are too close for calculation of T_{on} of Flatten *T* wave. In the context of the difference between mean values of lead II and lead III is a further step towards the investigation. Table 9 and graphical view in Figs. 3 (a) and (b) represent the difference between two findings. In case of further observation and investigation Fig. 3 (a) accounts for the finding the mean values of T_{on} parameter and efficiency factors of lead II, lead III and difference between two leads. Fig. 3 (b) pie chart representation of percentage composition of T_{on} parameter and efficiency factors that specifies that error ration between two leads is bit low.

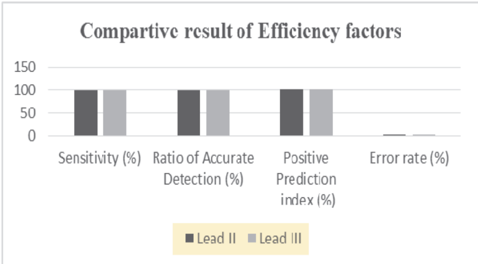

Fig. 2. Comparison view of lead II and lead III.

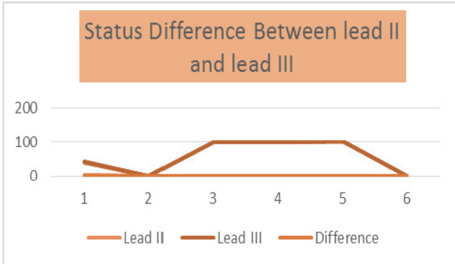

Fig. 3. (a) Graphical view of difference status between lead II and lead III.

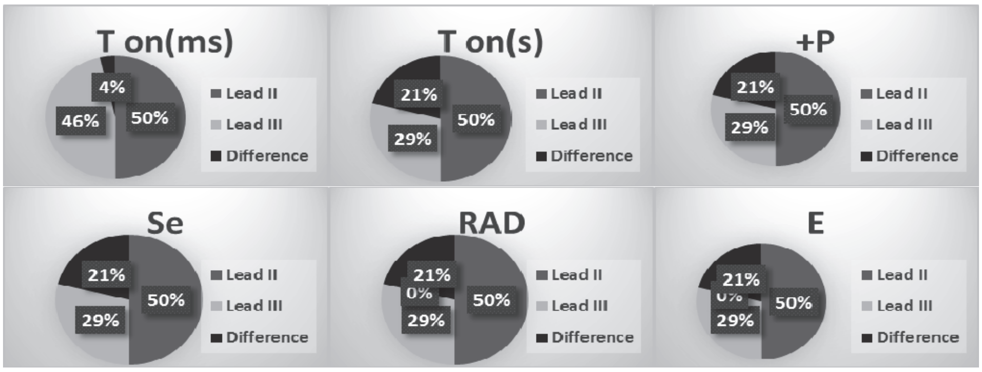

Fig. 3. (b) Percentage composition of lead II and lead III in terms T_{on} and efficiency factor.

Table 8. Compartive summary of both leads result.

T-onset Parameter and Efficiency factors	Lead wise Comparison	
	Lead II	*Lead III*
T_{on}	43.73 ms, 0.04497s	40.54ms, 0.0406s
S_e (%)	99.29	99.56
RAD (%)	99.29	99.56
P_+(%)	100	100
Error rate (%)	0.74	0.428

Table 9. Difference between lead II and lead III.

Leads Combination	*T*-onset(ms)	*T*-onset(s)	*Se*(%)	*RAD*(%)	(P_+)(%)	*E*(%)
Lead II	43.73	0.04497	99.29	99.29	100	0.74
Lead III	40.54	0.0406	99.56	99.56	100	0.428
Difference	*3.19*	*0.00437*	*0.27*	*0.27*	*0*	*0.312*

7. CONCLUSION AND FUTURE DIRECTION

This research article delivers the deterministic approach for calculating the T_{on} parameter of Flatten *T* wave. This efficient approach is an initial step towards nature determination of Flatten *T* wave. During the operational activities of this deterministic approach, using a core part of the TWA algorithm by taking the *R* peak as a fiducial point, such operational process reflects the involvement of dependencies factor during the investigation of T_{on} parameter of Flatten *T* wave. A high rate result of T_{on} parameter after the operation activities indicates the bigger achievement because the parametric solution of Flatten *T* wave is still a pending work for researchers. By using our best knowledge, the literature indicates previously no one work on the parametric solution of Flatten *T* wave. A parametric solution of Flatten *T* wave opens the door of nature determination which plays a vital role in a diagnostic purpose of MI affected patients. Evaluation of this deterministic approach manifests the high-efficiency factors and T_{on} parameter after experimental investigations. Showcase of these factors in terms of derivation of the mean (T_{on}) Sensitivity (S_e), Ratio Accurate Detection (*RAD*), Positive prediction index (P_+) and Error rate (*E*). These factors are highlighted in form of lead II T_{on} = 43.73 ms, 0.04497s, S_e = 99.29%, *RAD* = 99.29%, P_+ = 100%, *E* = 0.74% and lead III T_{on} = 40.54 ms, 0.0406s, S_e = 99.56%, *RAD* = 99.56%, P_+ = 100%, *E* = 0.428 %. These findings clearly reflect that error rate between two leads is negotiable but further operational qualitative improvements are highly desirable for further investigations in the context of derivation the other parameters of Flatten *T* wave.

In future, one may investigate the use of our proposed approach to calculate other key parameters such as T_{dur}, T_{peak}, T_{off}. Combining our method with wavelet analysis to further improve the performance can be another intriguing area for researchers. Secondly, such algorithmic solution will also be helpful for other areas like the beat to beat analysis (QT interval detection), premature ventricular contraction (PVC) and atrial fibrillation (AF).

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