

# T-Wave Morphology Evaluation in Healthy Subjects: The Effect of Posture on the Measurements

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## Abstract

*This study investigated the effect of posture on the T-wave morphology in healthy subjects. Standard 12-lead ECGs were digitally recorded from 70 healthy subjects. From each subject, 10 consecutive ECGs were taken in each of the supine, sitting, and standing positions. T-wave morphology indices included: the total cosine R-to-T (TCRT), normalized T-wave loop area (TLA), and relative T-wave residuum (TR). There was a trend towards a systematic change in measurements related to postural changes. TCRT significantly decreased when the position was changed from supine to sitting ( $p < 0.05$ ), and from sitting to standing ( $p < 0.05$ ). Similar pattern was found in the TLA ( $p < 0.05$ ). Conversely, TR increased significantly both in sitting and in standing compared to that in supine ( $p < 0.05$ ). It may be speculated that the increased sympathetic tone induced by postural tests leads to modifications of T-wave morphology detectable in digital ECGs.*

## 1. Introduction

Cardiac electrical instability has been considered as a most potent risk factor for sudden death [1]. Identification of the determinants and/or markers of electrical instability non-invasively remain important goals for research.

Ventricular repolarization abnormalities are known to be arrhythmogenic [2]. Early studies suggested that subtle fluctuations of ECG morphology might serve as an indicator of diminished cardiac electrical stability [3]. Newly developed T-wave morphology descriptors have been demonstrated to be powerful indicators of arrhythmic complications among patients with ventricular tachycardia/fibrillation [4]. This technique has also been shown to be promising in risk stratification of post myocardial infarction patients [5], though a more detailed experimental basis of the electrophysiological mechanism remains poorly understood.

Assessment of T-wave morphology quantifies repolarization abnormalities with the advantage being independent of the precise localization of end of T waves, which may overcome the major problem in conventional

QT studies [6,7]. We hypothesized that postural changes would increase sympathetic tone which may lead to modifications of T-wave morphology detectable by newer electrocardiographic technique. This study evaluated the effect of postural changes on the assessment of T-wave morphology in healthy subjects.

## 2. Methods

### 2.1. Study subjects

This study consisted of 70 healthy volunteers (mean age  $38 \pm 10$  years, range 13-60 years; 35 men). All study participants had a normal physical examination, a normal ECG and were not on any medication.

### 2.2. ECG recordings

Thirty consecutive standard 12-lead ECG recordings were taken in a supine, sitting and standing positions from each study subject. The serial ECGs were recorded one immediately after another without changing the electrode attachment. Patients were required to be quite and keep still during the whole recording period. After the first 10 recordings in supine position, study subjects were asked to sit up immediately for another 10 recordings, and then to stand up for the last 10 recordings. ECG recording was reinitiated as soon as the obvious noise caused by a postal change disappeared. Data acquisition of each ECG took about 30 seconds. To obtain the 30 ECGs, including electrocardiograph handling and data storage, approximately 30 minutes were needed to complete the study protocol.

All ECGs were recorded using a commercially available digital electrocardiograph (MAC VU, GE Medical Systems, WI, USA) with a sampling rate of 500 Hz. All raw data were stored on floppy disks and downloaded to a personal computer for further analysis. The analytical system was implemented on a standard personal computer.

### 2.3. T-wave morphology analysis

Analysis of the digital ECG recordings were performed in a fully automatic manner with a custom-

developed software implemented on a personal computer [6]. The analysis program performs a singular value decomposition of the ECG signal into a minimum dimensional space. Based on the decomposition, several descriptors were calculated of spatial and temporal variations of T-wave morphology and repolarization wavefront direction [6]. Three T-wave morphology descriptors were derived and analyzed in this study [6,7].

## 2.4. T-wave morphology indices

T-wave morphology indices included: the total cosine R-to-T (TCRT), normalized T-wave loop area (TLA), and relative T-wave residuum (TR).

TCRT measures the vector deviation between the depolarization and repolarization waves by calculating cosine values between the 3-dimensional R- and T-wave loop vectors within the optimized decomposition space. Negative values correspond to large differences in the orientation of the depolarization and repolarization loops. While the mathematical definition is different, the concept is similar to that of the vectorial angle of ventricular gradient.

TLA describes the shape and irregularity of the T-wave loop by expressing its area as a fraction of the rectangle that encompassed the loop.

TR is derived from the proportion between T-wave non-dipolar and dipolar components. The parameter represents an attempt to characterize repolarization heterogeneity [7].

## 2.5. Statistical analysis

Comparison of the measurements of the T-wave morphology indices between groups or between positions were performed using unpaired or paired Student's *t* test where appropriated.

Data were presented as mean  $\pm$  standard error. A *p* value of  $< 0.05$  was considered statistically significant.

## 3. Results

There was a trend towards a systematic change in the measurements related to postural maneuvers (Table 1, Figure 1). Significant changes were found in all measurements obtained in sitting or standing ECGs as compared with those from supine ECGs. TCRT significantly decreased when the position was changed from supine to sitting ( $p < 0.05$ ), then decreased further from sitting to standing ( $p < 0.05$ ). Similar trend was found in the TLA while significantly smaller values of TR was found in sitting and in standing position than that in supine position ( $p < 0.05$ ). Conversely, TR increased significantly both in sitting and in standing compared to that in supine position ( $p < 0.05$ ).

Table 1. T-wave morphology measurements in relation to positions (mean $\pm$ SE).

	Supine	Sitting	Standing
TCRT	0.509 $\pm$ 0.035	0.466 $\pm$ 0.043*	0.267 $\pm$ 0.050*
TLA	0.624 $\pm$ 0.014	0.604 $\pm$ 0.014*	0.555 $\pm$ 0.016*
TR	0.0004 $\pm$ 0.0003	0.0005 $\pm$ 0.0005*	0.0007 $\pm$ 0.0009*

\* $p < 0.05$  for comparison of the measurements with those from supine ECGs. TCRT = the total cosine R-to-T; TLA = normalized T-wave loop area; TR = relative T-wave residuum.

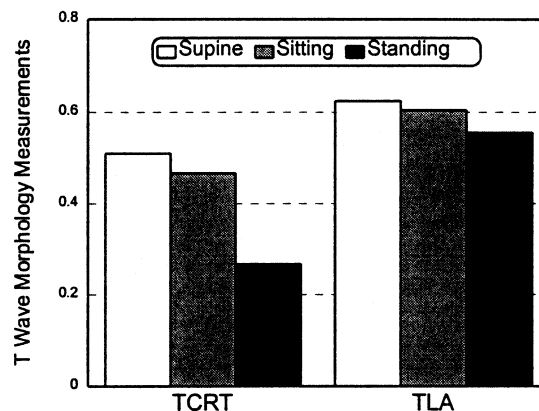


Figure 1. Bar graphs illustrate the alterations in the T-wave morphology measurements in relation to the changes in posture.  $P < 0.05$  for comparison of the measurements in either sitting or standing position with those from supine ECGs. TCRT = the total cosine R-to-T; TLA = normalized T-wave loop area.

## 4. Discussion

### 4.1. The main findings

From 70 healthy subjects, we observed that the numeric values of the TCRT and TLA were significantly lower in the sitting position, and decreased further in the standing position compared to that in supine position in healthy subjects. Conversely, the values of TR significantly increased with the changes in the position from supine to sitting and from sitting to standing.

### 4.2. Evaluation of cardiac autonomic status and ventricular tachyarrhythmias

The link between autonomic modulation and arrhythmic risk is well established. In clinical practice,

autonomic tone can be assessed by heart rate variability analysis and baroreceptor sensitivity test. The heart rate variability analysis obtained from long-term ambulatory ECG concerns primarily vagal tone, whereas the baroreceptor sensitivity test discloses the capability of the parasympathetic nervous system to react to a gross stimulus and thus concerns primarily vagal reflexes [8]. Because of the strong relation of autonomic tone and vulnerability to arrhythmias measurement of autonomic tone would be expected to be incorporated into risk stratification algorithm.

Ventricular repolarization abnormalities are arrhythmogenic. Attempts have been made to characterize and quantify the abnormalities from the surface ECGs. Assessment of T-wave morphology descriptors is expected to play such a role [5,9]. It was shown that the autonomic effect on ventricular repolarization was detected using these newly developed T-wave morphology descriptors in healthy subjects [10]. In cardiac patients, Zabel et al. [5] demonstrated that TCRT yielded independent predictive value in multivariate analysis using Cox regression model and suggested that computerized T-wave morphology analysis of the 12-lead ECG permit independent assessment of post myocardial infarction risk. The predictive power of TCRT may be explained in part by its ability to detect the effect of alteration in autonomic activities on ventricular repolarization, though experimental evidence to reveal the mechanism is lacking.

### 4.3. Postural tests and ventricular repolarization

Previous studies showed that postural changes affected ventricular repolarization evaluated by conventional techniques [11]. Little data exist regarding the effect of autonomic modulation on ventricular repolarization by evaluating T-wave morphology. In present study, using digital surface ECG data the effect of postural changes on ventricular repolarization was observed. Our findings were consistent with that reported recently by Batchvaron et al, in which 12-lead Holter ECG recordings were used [10]. Both of these studies showed that these T-wave morphology indices were sensitive to the modification of sympathetic activities.

### 4.4. Study limitations

In this study, the effect of postural changes on the ventricular repolarization was evaluated by rather simple tests. The effects of sympathetic activation and heart rate changes on ventricular repolarization could not be separated. It remains unknown if these findings apply to patients with cardiac disorders. Further studies are needed to confirm our findings and the electrophysiological mechanism has to be further investigated.

### 4.5. Study implications

The clinical importance for assessment of ventricular repolarization has been well recognized because of the association between sympathetic overdrive, ventricular repolarization abnormalities and arrhythmogenesis [1,2,8,9].

Our findings show that increased sympathetic tone induced by postural changes leads to modifications of T-wave morphology that are detectable in digital surface ECGs. This may be one of the explanations for the known proarrhythmic properties of sympathetic overdrive in cardiac patients.

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