Beat-to-Beat QT Interval Variability in the 12 Lead ECG

Muhammad A Hasan, Derek Abbott, Mathias Baumert

The University of Adelaide, Adelaide, Australia

Abstract

Beat-to-beat QT interval variability (QTV) is a marker of ventricular repolarization lability. Increased QTV has been associated with cardiac mortality. The aim of this paper was to investigate QTV in the 12-lead ECG and the potential effect of age. Short-term ECGs (2 mins) of 48 healthy males were studied. Beat-to-beat QTV was measured in each lead by using Berger's template-stretching algorithm. We observed significant differences in QTV of different leads (ANOVA test: $p < 0.0001$). In addition, we investigated the effect of age by dichotomizing the data set based on the median age. Two-way ANOVA showed no significant differences in QTV of older males compared to younger males. In conclusion, the magnitude of QTV depends on the lead selected for measurement.

1. Introduction

The measurement of QT interval in the standard 12-lead electrocardiogram (ECG) is of clinical importance. The QT interval is defined as the time differences between Q-wave onset and T-wave offset (duration from the onset of depolarization to the completion of repolarization). It is well established that QT interval prolongation or shortening is associated with the tachyarrhythmia and sudden cardiac arrest (SCA) [8-10].The QT interval variability is defined as the dynamic variations in the QT interval durations. Recently, it has been indicated that increased beat-to-beat QT interval variability is a risk factor for cardiac or non-cardiac arrhythmias and sudden cardiac death (SCD) [1-7]. Elevated QTV has also been reported in patients with obstructive sleep apnea syndrome [5].

However, the mechanisms underlying QTV are incompletely understood. Besides electrical restitution, which reflects the intrinsic adaptation of the action potential duration to changes in cycle length, the autonomic nervous system is thought to play a key role in the genesis of beat-to-beat QT interval variability.

The aim of this study was to analyse inter-lead differences in beat-to-beat QTV in the standard 12-lead ECG and to investigate the effect of age.

2. Methods and methodology

2.1. Study subjects

The ECG data has been obtained from the PTB diagnostic database (http://www.physionet.org/physiobank/database/ptbdb/) and included 48 healthy males (24 young, age 17-37 yrs vs. 24 old, 37-69 yrs). Each ECG data record included 15 simultaneously measured signals: the standard 12 leads (I, II, III, aVR, aVL, aVF, V_1- V_6) together with the three Frank leads. The Frank lead ECG has been excluded from this study. For each ECG signal, the recording duration was approximately 2 minutes and the sampling frequency was 1000 Hz, with 16-bit resolution (± 16.384 mV).

2.2. Analysis of QT variability

To analyse the beat-to-beat QT interval variability, it is essential to find the Q-wave onset and T-wave offset in the ECG pattern. Although, sometimes it becomes a difficult task in the presence of noise sources and artefacts.

In this study, we have used the algorithm proposed by Berger and co-workers [1]. Here, the operator can define a template of QT interval by selecting the onset of Q-wave and offset of T-wave for one beat in a particular lead (e.g. lead I) from 12-lead ECG. The designed algorithm then finds the QT interval of all other beats in that particular lead by determining how much each T-wave must be stretched or compressed to best match with the template [1]. If the operator selects a longer/shorter QT template, all of the QT intervals will be biased accordingly. In this way, a relatively robust estimation of QT interval is achieved by considering the whole T-wave instead of commonly applied threshold techniques that are based on determining the end of the T-wave and that is sensitive to artefacts and noise sources [1]. The same QT template is considered to obtain the beat-to-beat QT interval in rest of the leads for one subject. In this fashion, the beat-to-beat QT interval was determined for all studied subjects.

2.3. Statistics

For statistical analysis, GraphPad Prism 5® and Microsoft Excel version 2007 were used. All values were expressed as mean ± standard deviation. The one-way ANOVA was used to test for differences in QTV between different leads in all subjects. The two-way ANOVA was applied to test for QTV differences between leads for the effect of age. We dichotomized the data set to groups of younger and older males based on the median age. For post hoc analysis the bonferroni post-test was used to determine differences between multiple groups of leads. The values were considered statistical significant when $p < 0.05$.

3. Result

The bar graph (mean with standard deviation) of beat-to-beat QTV for all studied subjects is shown in Figure 1.

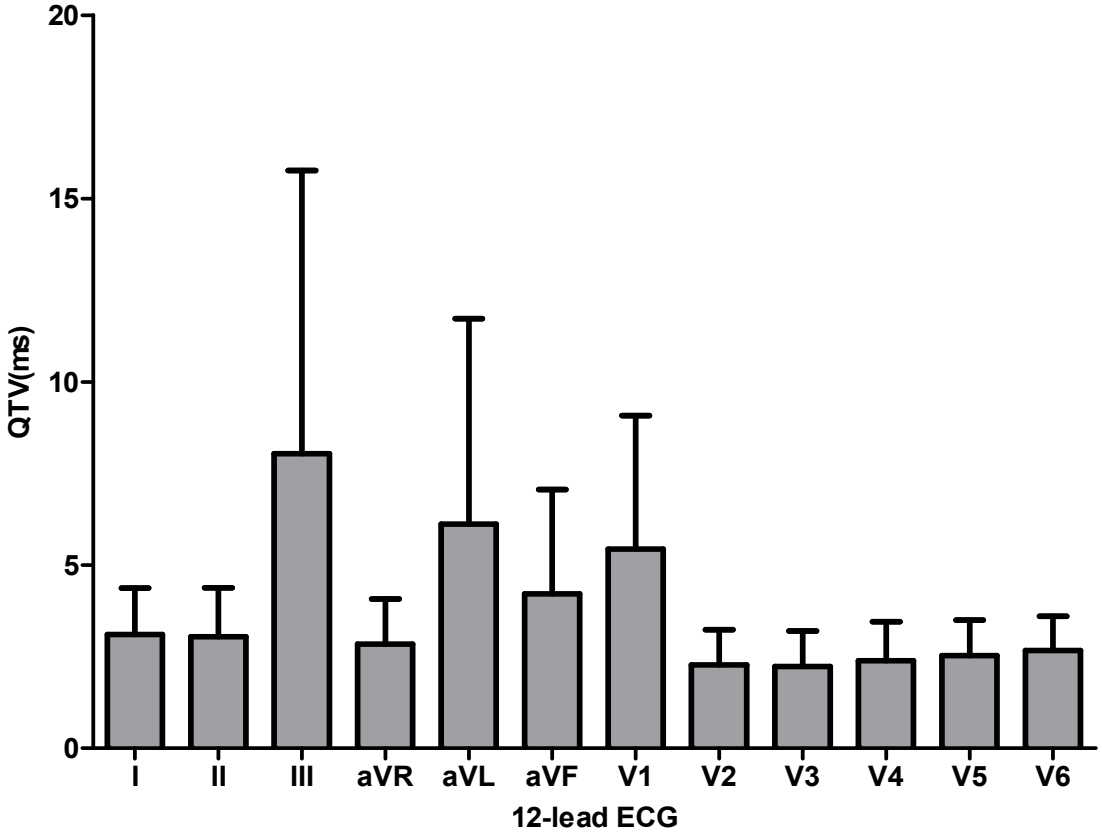

Figure 1. Mean with SD of QTV for overall subjects

The highest QTV was observed in lead III (8.04 ± 7.72 ms) followed by lead aVL (6.12 ± 5.6 ms), V_1 (5.44 ± 3.64 ms) and lead aVF (4.22 ± 2.85 ms). In all remaining leads (I, II, aVR, V_2-V_6) mean QTV was lower than 4 ms. ANOVA revealed significant inter-lead differences in QTV ($F = 16.23$, $p < 0.0001$). In addition, the post-hoc test results (Bonferroni's multiple comparison test) are summarized in Table 1.

Table 1: Post-hoc test (significant differences in the magnitude) of beat-to-beat QT variability in 12-lead ECG

Lead	**II**	**III**	**aVR**	**aVL**	**aVF**	**V_1**	**V_2**	**V_3**	**V_4**	**V_5**	**V_6**
I	n.s.	***	n.s.	***	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
II		***	n.s.	***	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
III			***	n.s.	***	**	***	***	***	***	***
aVR				***	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
aVL					n.s.	n.s.	***	***	***	***	***
aVF						n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
V_1							***	***	***	***	**
V_2								n.s.	n.s.	n.s.	n.s.
V_3									n.s.	n.s.	n.s.
V_4										n.s.	n.s.
V_5											n.s.

*** - $p < 0.001$, ** - $p < 0.01$, * - $p < 0.05$, n.s. – not statistically significant

The mean values and standard deviations of beat-to-beat QTV of younger and older subjects are shown in Table 2. The mean values of QTV in leads III and aVL appeared to be higher in older subjects than in younger subjects. In all other leads younger males seemed to have higher QTV than older males. However, no significant differences were found in overall age effect on QTV.

Table 2: QTV in younger and older subjects

Lead	**Young (ms)**	**Old (ms)**
I	3.41±1.43	2.79± 1.04
II	3.31±1.41	2.77± 1.24
III	6.76±5.36	9.33±9.47
aVR	3.19±1.39	2.51±0.95
aVL	4.73±1.80	7.51±7.54
aVF	4.66±3.38	3.77±2.18
V_1	6.11±3.54	4.77±3.69
V_2	2.64±1.02	1.93±0.76
V_3	2.54±0.98	1.92±0.87
V_4	2.60±1.05	2.18±1.06
V_5	2.85±1.05	2.20±0.78
V_6	2.91±0.97	2.43±0.86

4. Discussion

Previously, the quantification of QTV for beat-to-beat analysis was studied by looking at the single lead or couple of leads from 12-lead ECGs. The lead III has been used to assess the relationship between beat-to-beat QTV and sympathetic nervous activity in hypertension patients [14], lead I and II has also been used for dilated cardiomyopathy [1], lead II has used to observe the age effect on the QT interval variability [12]. However, the systematic observations by considering the appropriate leads in 12-leads were usually ignored in previous studies. Therefore, we have observed the beat-to-beat QTV on each individual leads in studied subjects.

In earlier research, it has been found that QTV is decreased with the increasing age when lead II was considered [12]. We observed that the deviations of beat-to-beat QTV in younger subjects were higher than in older age subjects in most of the leads (I, II, aVR, aVF, V_1-V_6). However, few exceptions were also found in our investigations, i.e. leads III and aVL, where QTV of older subjects appeared to be higher than in younger subjects.

5. Conclusion

Our results indicate variations in QTV of the 12 standard ECG leads. The amount of QTV depends on the lead that is investigated.

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Address for correspondence.

Name: Muhammad Asraful Hasan
Address: School of Electrical and Electronic Engineering
The University of Adelaide
Adelaide, SA 5005, Australia
Email: muhammad.hasan@adelaide.edu.au