Influence of Psychological Stress on QT Interval

Chandan Karmakar[1], Mohammad Hasan Imam[1], Ahsan Khandoker[1,2], Marimuthu Palaniswami[1]

[1]The University of Melbourne, Melbourne, Australia
[2]Khalifa University of Science, Technology and Research, Abu dhabi, UAE

Abstract

This paper investigates the influence of psychological stress due to driving in city traffic condition on beat-to-beat QT interval. Electrocardiogram (ECG) signal of 16 subjects were analyzed from Physionet "drivedb" database. Total 32 segments of ECG signal was selected from all subjects. 16 of which were recorded during "Stressed" condition and rest 16 were in "Unstressed" states. Each segment was 5 minutes long and QT intervals were extracted using Berger's template matching algorithm. Heart rate corrected QT (QTc) intervals was calculated using methods proposed by Bazett, Fridericia and Framingham. The mean and standard deviation of each QTc interval time series was calculated as a feature describing average length and variability of QTc interval. The results showed that the mean QTc was lower in "Stressed" condition than "Unstressed", however none of the differences were statistically significant. In contrast, the variability of QTc intervals were higher in "Stressed" segments than the "Unstressed" ones and the difference was statistically significant. However, such difference was not present in RR intervals. In summary, QT was not prolonged due to stress but beat-to-beat QT variability increased in "Stressed" condition and this can be an effective marker to detect psychological stress.

1. Introduction

Psychological stress is neurologically related with cognitive functions and it increases in certain cognitive tasks like problem solving, decision making, playing games and driving. A recent definition asserts "stress should be restricted to conditions where an environmental demand exceeds the natural regulatory capacity of an organism" [1].

Stress affects different cardiovascular responses and stress induced autonomic nervous system activation might also trigger lethal arrhythmias through alterations of the neural transmissions to the heart [2]. Therefore electrocardiogram (ECG) derived heart rate variability (HRV) analysis is an obvious choice for detecting psychological stress [3-5]. Epidemiologic evidence suggests that there is a relationship between stress and cardiac morbidity and mortality in susceptible individuals [6].

The QT interval of the resting ECG reflects the time between the onset of electrical activation and its recovery and called repolarization duration. QT is affected by a number of factors, both internal (genetic, physiologic, and pathophysiologic) and external (food, drugs, temperature) for a given individual. The QT is strongly influenced by heart rate (i.e. RR or cardiac, cycle length), so heart rate correction is required in the analysis of repolarization duration and such heart rate corrected QT is termed as QTc. In general, women have a longer (~ 10 to 20 ms) QTc than men [7, 8] and it was reported that there is a positive correlation between age and QTc [8]. A mean lengthening of QTc by 13 ms and increased variability of QTc have been observed during sleep[7, 9].

Previous published reports provided conflicting data on the effect of mental stress on the QT-interval duration. It was reported that the QT interval prolonged when physicians got alarm calls and being awakened with bad news in the night [9, 10]. In contrast, laboratory-based studies reported QT-interval shortened during stressful interviews, Stroop color-word test and mental arithmetic as an effect of mental stress[11, 12]. Although these studies used raw QT intervals, Stroop color-word test with heart rate corrected QT and fixed rate ventricular pacing with high degree of atrioventricular block has also shown QTc shortening [16-17].

In order to explore the influence of psychological stress on QT interval, we prospectively examined the prolongation or shortening of repolarization as mean QT interval and variability of repolarization as QTVI as well as standard deviation of QT, in subjects with and without stress.

2. Data & methods

2.1. Data

ECGs were taken from Physionet Stress Recognition in

Automobile Drivers (drivedb) database From this database, a total of 16 healthy subjects' data were taken out of 17 subjects' recordings. One recording (drive01) was dropped from our study due to problem in T wave analysis. The detail of this study protocol i.e., driving protocol, driving period, stress measurement and validation of stress level assessment techniques etc. were described by Healy et al. [13].

In this study, we have used 5 minutes ECG and respiration signal during resting and high stress (city driving) conditions. Recordings of resting condition were treated as stable physiological condition and grouped as "Unstressed", whereas recordings of city driving condition were considered as stressed condition data and grouped as "Stressed". The ECG sampled at 496Hz was recorded with a modified lead II configuration for reducing the effect of motion artefact and for better detection of R waves.

QT intervals were detected using a semi-automated template-matching algorithm proposed by Berger et al [14]. This algorithm is used in many clinical studies with reliable results describing ventricular repolarization variability [15]. The QT interval was calculated as the difference between Q wave onset and T wave end point (i.e. QTend interval).

2.2. Heart Rate corrected QT (QTc) and beat-to-beat QT interval and variability measurement

The most commonly used equation to correct the QT interval for heart rate is Bazett's square root formula [16]:

$$QTc_b = \frac{QT}{\sqrt{RR}} \qquad (1)$$

Contemporary to Bazett's work, the study by Fridericia used a detailed mathematical evaluation of QT correction and approximated the formula as [17]:

$$QTc_f = \frac{QT}{\sqrt[3]{RR}} \qquad (2)$$

Another most commonly used linear formula derives from the Framingham Heart study, named Framingham or Sagie formula [18]:

$$QTc_l = QT + 0.154(1 - RR) \qquad (3)$$

Mean of raw QT, QTc_b, QTc_f and QTc_l time-series and termed as QT_{rm}, QTc_{bm}, QTc_{fm} and QTc_{lm} respectively. Standard deviation of the same set of time-series was measured and termed as $SDQT_r$, $SDQT_b$, $SDQT_f$ and $SDQT_l$ respectively.

Temporal beat-to-beat QT variability was measured as previously described for surface ECG analysis [14]. The heart rate mean (HR_m) and variance (HR_v) and QT interval mean (QT_m) and variance (QT_v) were computed from the respective time series. A normalized QTVI was derived according to equation:

$$QTVI = log_{10}[(QT_v/QT_m^2)/(HR_v/HR_m^2)] \qquad (4)$$

The $QTVI$ was measured for raw QT, QTc_b, QTc_f and QTc_l time-series and termed as $QTVI_r$, $QTVI_b$, $QTVI_f$ and $QTVI_l$ respectively.

2.3. Heart rate variability (HRV) parameters and statistics

Besides QT time-series based parameters, we have also calculated mRR (mean of RR time-series) and sdRR (standard deviation of RR time-series) as HRV measures.

Non-parametric Mann-Whitney U-Test was carried out for statistical comparisons between 'Stresssed' and 'Unstressed' group. A value of $p < 0.05$ was considered significant. All the statistical calculations were carried out in MATLAB R2012b.

Table 1: Mean ± SD (standard deviation) values of RR intervals (Mean RR, SDRR), QT intervals (QT_{rm}, QTc_{bm}, QTc_{fm}, QTc_{lm}, $SDQT_r$, $SDQT_b$, $SDQT_f$ and $SDQT_l$) and QTVI parameters ($QTVI_r$, $QTVI_b$, $QTVI_f$ and $QTVI_l$).

Parameter	Unstressed	Stressed	p value
mRR	833.54 ± 109.42	782.41 ± 109.58	0.28
sdRR	53.91 ± 19.02	65.41 ± 16.40	0.09
QT_{rm}	339.94 ± 28.83	326.07 ± 30.52	0.20
QTc_{bm}	373.17 ± 18.62	370.25 ±17.58	0.50
QTc_{fm}	361.15 ± 20.21	354.63 ±20.47	0.40
QTc_{lm}	365.60 ± 18.07	360.02 ±17.96	0.32
$SDQT_r$	4.80 ± 2.90	10.13 ± 5.16*	0.003
$SDQT_b$	12.22 ± 4.87	19.11 ± 4.83^	2.59e-4
$SDQT_f$	8.43 ± 3.73	14.60 ± 4.81^	1.50e-4
$SDQT_l$	8.78 ± 3.42	14.02 ± 4.10^	2.59e-4
$QTVI_r$	-3.01 ± 1.29	-2.03 ± 1.21*	0.01
$QTVI_b$	-1.21 ± 0.65	-0.92 ± 0.48*	0.03
$QTVI_f$	-1.88 ± 0.86	-1.37 ± 0.69*	0.02
$QTVI_l$	-1.81 ± 0.77	-1.49 ± 0.53*	0.04

* p<0.05; ^ p<0.001

3. Results

Mean and SD (standard deviation) values of mRR, sdRR, QT_{rm}, QTc_{bm}, QTc_{fm}, QTc_{lm}, $SDQT_r$, $SDQT_b$, $SDQT_f$, $SDQT_l$, $QTVI_r$, $QTVI_b$, $QTVI_f$ and $QTVI_l$) are shown in Table 1. mRR (i.e. Mean RR interval) decreased and sdRR increased in 'Stressed' group than 'Unstressed' group subjects. Therefore, none of them showed any significant difference between two groups. Although, mean values of QT_{rm}, QTc_{bm}, QTc_{fm} and QTc_{lm} are higher in 'Stressed' group than 'Unstressed', none of them are significantly different between two groups.

In contrast, mean values of $SDQT_r$, $SDQT_b$, $SDQT_f$ and $SDQT_l$ are higher in 'Stressed' group than 'Unstressed' with statistical significance. However, the standard deviation of corrected QT ($SDQT_b$, $SDQT_f$ and $SDQT_l$) showed much higher statistical difference with p<0.001 between 'Stressed' and 'Unstressed' group than standard deviation of raw QT (QT_{rsd}) with p<0.05.

Similar to standard deviation of QT intervals, mean values of beat-to-beat QT variability parameters of both raw and corrected QT time-series ($QTVI_r$, $QTVI_b$, $QTVI_f$ and $QTVI_l$) were found higher in 'Stressed' group with statistical significance (p<0.05) than 'Unstressed' group.

The errorbars (Mean ± SD) of standard deviation of QT and QTVI parameters for both 'Stressed' and 'Unstressed' group were shown in Figure 1.

4. Discussions

The main goal of the present study was to evaluate the influence of psychological stress on duration and variability of QT interval. In this study, we used the general QT correction approaches [16-18], however these methods are strongly criticized by another previous study due to complex inter-individual variation of QT-RR interaction [19]. On the other hand, the superior concept of subject specific QT correction is difficult to achieve for all study, since it requires a number of QT/RR data sets for each subject with adequately broad range of heart rate variation. Moreover, it has been reported that in resting conditions with heart rates in the 60–90 beats/min (i.e. RR intervals of 666ms to 1000ms) range, most formulae provide almost equivalent results for the diagnosis of QT prolongation. Since the mean RR intervals of both groups in this study were well within this range, we believe that the used QT correction approaches are valid for this study.

In this study, we found insignificant shortening of QT interval duration in 'Stressed' group, which supports the results reported in various previous studies [11, 12, 22]. However, this finding contradicts with the study by Andrassy et. al. [20, 21], which reported significant QT-interval prolongation in stress. Although stress induced due to driving is a type of active mental stress, the difference could be due to the moment of data collection. In contrast to their study, we collected the 5 minutes ECG segment from middle of stress event rather than at the launching. Another reason for the difference could be the use of global QT correction approach in place of individual QT correction approach.

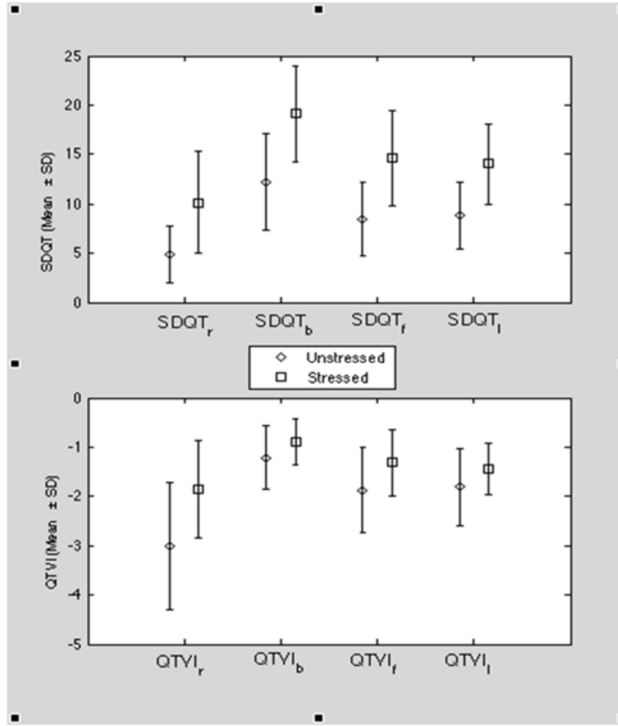

Figure 1. Errorbar (Mean ± SD) plots showing the trends in the variations SDQT ($SDQT_r$, $SDQT_b$, $SDQT_f$ and $SDQT_l$) and QTVI ($QTVI_r$, $QTVI_b$, $QTVI_f$ and $QTVI_l$) parameters within 'Unstressed' and 'Stressed' groups.

In this study, we found significantly increased QT variability in 'Stressed' group compared to 'Unstressed' group (using all QTVI parameters), which may be due to withdrawal of parasympathetic influence on the heart rate [24]. Subsequently, negative QTVI values were observed in both groups indicating a continuing dominance of RR variability over QT variability. The SDQT parameters also showed the similar trend of variation as QTVI in 'Stressed' and 'Unstressed' groups. However, SDQT parameters of corrected QT intervals showed better statistical significance in differentiating 'Stressed' and 'Unstressed' group than QTVI parameters. Since SDQTc measures the variability of QT series after rate correction, the autonomic effects on QT variability may be strongly pronounced in this measure compared to QTVI, which is an overall measure of RR and QT variability.

5. Conclusion

In this study, we highlighted the influence of stress on duration and variability of QT interval. For variability, we have used both traditional QTVI analysis as well as standard deviation of raw and corrected QTc time-series. The results show that stress affects mainly the QT variability but there is no significant impact on QT duration. Both standard deviation of QTc and QTVI measure reflects significant difference in variability between 'Stressed' and 'Unstressed' group. However, a better statistical significance is illustrated by standard deviation based variability measure than QTVI. So, variability of QTc could be a suitable parameter for detecting and evaluating this special state of humans (i.e. psychological stress) with short-length (5 minutes) ECG signal.

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Address for Correspondence:

Chandan Karmakar
Research Fellow
Department of Electrical & Electronic Engineering
University of Melbourne, Melbourne, Australia
Karmakar@unimelb.edu.