Challenges to QT Interval Variability Analysis in Mobile Applications

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Introduction

The QT interval in an electrocardiogram (ECG) reflects complex processes affecting the repolarization of ventricular myocardium. Increased QT interval variability (QTV) is thought to be caused by ventricular repolarization lability and has been associated with cardiac mortality. As changes in QTV are typically small, correct identification of subtle QT interval changes is a major concern in QTV analysis. Recent publications have shown that template-based methods are more robust than traditional methods for QT interval extraction on a beat-to-beat basis.
However, most studies are limited to non-movement ECG recordings, we want to analyze in this study the power of QT interval extraction for mobile non-stationary ECG recordings. The investigation is thought to lay the fundamentals to future mobile QT analysis.

Methods

A novel mobile multi-sensor hardware platform for long-term ECG monitoring, invented and provided by Fraunhofer Institute for Photonic Microsystems (Dresden, Germany), was used. Additionally to a 24-Bit analog front-end for biopotential measurements on three ECG channels, a nine axes (gyroscope, accelerometer, and magnetometer) motion sensor is integrated. 10 records (sampled at 250 Hz) of the first pilot study, obtained from 7 test subjects (1 female, 6 male) were analyzed. The records are at least 65 min long and contain about 25 minutes of sport exercise such as running, cycling, sport climbing or acrobatic training.
For our investigation, two-dimensional signal warping (2DSW) was used in order to extract the QT interval. 2DSW relies on template matching techniques and is able to account for complex changes in morphology of the ECG waveform. It has been shown that 2DSW tracks QT changes with high precision while being robust toward signal artifacts. We applied 2DSW with the same algorithmic parametrization as we used for in-patient recordings. Recordings were splitted in 10 min long segments to consider activity changes. QT interval for QTV calculation and best-fit distance of matched template for signal quality evaluation were extracted for each beat. To remove motion artefacts all beats with a best-fit distance higher than 20 µV/ms were rejected. Potential relations between QTV, motion and signal quality are segmentally compared. To determine motion activity we calculated normalized signal magnitude area (SMA).

Results

Measured best-fit distance of all 69 segments is about 28 ± 17 µV/ms and in-segment rejection rate is about 60 ± 18 % (mean ± std). Because of high rate of motion artifacts, segments with less than 20 remaining beats were excluded from further analysis. The segmented QT interval standard deviation of the remaining 62 segments is about 22 ± 18 ms. We found strong correlation between QTV and signal quality ($r = 0.5$, $p < 0.001$) and slight correlation between QTV and SMA ($r = 0.25$, $p < 0.05$).

Conclusion

Increased QTV by patients during sport exercise, possibly reflects sympathetic activity in these specific physiological conditions, could be measured. However, increased QTV could also be caused by low signal quality. Therefore, further investigations need to analyze the relation between reasons of low signal quality and increased QTV more in detail to determine an ECG signal, which is acceptable for QTV analysis.