An Augmentative and Portable QTc-Observer(QTO-Q2) to Facilitate More Purposeful Outpatient Monitoring

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Abstract

A tele-medical approach for monitoring and detecting prolonging QT-intervals via cellular equipments is proposed in this paper. Currently, the procedures for detecting Longed QT Syndrome (LQTS) involves taking a 1 time preliminary prognosis followed by a comprehensive long time hospital or laboratory bound monitoring; the latter is only conducted if and only if the former is tested positive. However, if the preliminary prognosis fails due to the absence of the symptoms during the instance of testing, the subject may be declared with a false clean bill of health. In this modern day and age where telemedicine is becoming a more important aspect of conventional medicine, it is sensible that the conventional methods be augmented with ambulatory long-term monitoring to better detect LQTS for people suspected of it. The QTc-Observer (QTO or Q2) is developed to monitor specifically QT intervals for the detection of LQTS. Built on top of the existing MobiCare System [1] and a newly developed QT/QTc trend interval measure algorithm [2], the Q2 is connected to an all-day monitoring center for continuous observations by medical professionals.

1. Introduction

The QT/QTc-interval is an important and well-known measure of the user's cardiac capabilities to polarize and de-polarize the heart. Prolongation of the QT/QTc interval will lead to ventricular arrhythmias, Torsade-De-Pointes, and ultimately untimely deaths. The signs of Long QT Syndrome or the prolonging of the QT-intervals cannot be immediately diagnose at a single reading. Yet, in outpatient monitoring with regards to a patient after a heart surgery or on medication for the heart, this is a crucial vital sign to take note of. The QT-interval is an indication of the responsiveness to the effects of the medical intervention that patient with regards is having. The interaction of daily activities in external environments may affect the effects of the medical intervention.

The proposed technology implements the QT/QTc trend interval measurement algorithm [2] on the mobile cellular equipments. The technology utilizes a third party Bluetooth-enabled ECG acquisition unit to capture the ECG data. The capture data is transmitted via Bluetooth to a cellular phone for processing. The processed data is forwarded to a data-collection center via cellular networks. The clinicians and doctors can then immediately monitor the progress of their medical intervention via the data-collection center. And if any dire abnormalities were to arise during the trials, the patient can then be immediately contacted to go for immediate aid. This real-time point-of-assistance is possible because this proposed technology sits on the current MobiCare Information Networks [1].

Figure 1. MobiCare HealthCare Framework that is utilized by this approach

2. Methodology

2.1. The gap

Currently, the guidelines for QT intervals collection and measurements in hospitals are stated by the ICH [3]. The processing of voluminous ECG data for QT/QTc intervals is tedious and expensive. The economic and practical solution is to employ certified medical labs [4, 5] for analysis. This is slow as the process of data collection and processing are sequential.

There are portable but cumbersome units [6] that measure QTc intervals but they are more suited for emergencies purposes. Hence, there are no feasible solutions to expedite the current QT interval detection. Moreover, immediate physiological information that occurred during the monitoring when the patients are offsite is lost.

2.2. Improvisation

To improvise on the current settings of outpatient monitoring, a mobile solution that is able to take in short term information and make a preliminary prognosis is required. Based on our previous research [2] and the MobiCare Framework [1], Q2 is our developed prototype combining [1] and [2].

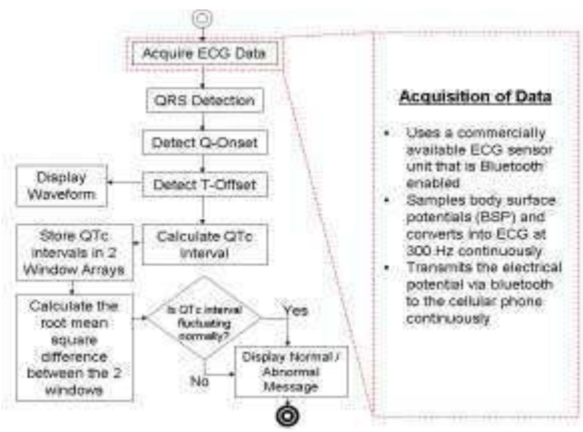

Figure 2. Explanation of Data Acquisition, with Detailed Process Flow Diagram

The data is acquired using a commercially available ECG sensor; Fig 2. The collected ECG is sent via Bluetooth to the cellular phone for processing. Once onboard the cellular phone; Fig 3, the algorithms present in MobiCare [1] will begin detecting for Q, R and T waveforms. The consecutive R waveforms of a full ECG waveform, R-peaks, will form the N-N intervals. The difference in time between Q and T waveforms will be the QT-interval. The QT-intervals is one of the most important key factors in predicting if a person is likely to have prolonged or shortened QT syndrome.

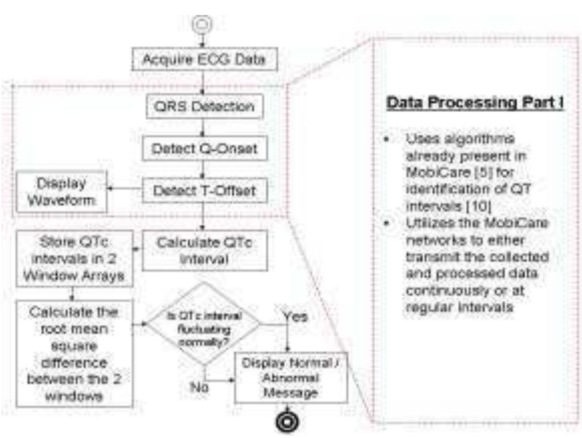

Figure 3. Explanation of Data Processing I, utilizing MobiCare [1], with Detailed Process Flow Diagram

After the QT-interval with its corresponding NN-interval is correlated and obtained, the QTc interval is calculated; Fig 4. The QTc interval is the QT interval corrected against its heart rate. The QTc interval is used to reduce false positives due to slower heart rate. Bazett's formula of standard clinical correction is used in this approach. The caveats of the formula are still valid. However, due to the approach of trend analysis in the later parts, the severity of the caveats may be lessened.

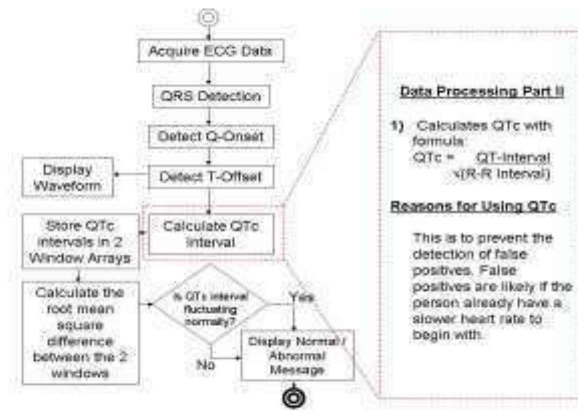

Figure 4. Explanation of Data Processing II, QTc Interval Calculation, with Detailed Process Flow Diagram

Following the techniques in [2], the QTc intervals are stored into buffers after they are calculated. Storage of QTc intervals is for trend analysis. In this preliminary prototype, QTc trends collected over time that exhibits high degree of deviations are being observed. The sliding window strategy in [2] is used to compare the trends as the QTc intervals are outputted by the previous processes. The latest window will be compared to the immediate window previous to the current one. The definition of previous window is dependent on the size of the window being observed. For example, if window size is 5, the first trend window comparison will begin at when there are 10 QTc intervals in the buffer. The current window will be QTc intervals 6-10 and the previous window will be QTc intervals 1-5. The second trend comparison would occur when the next 5 samples are available. Hence, the current window would now be QTc interval 11-15 and previous window would be QTc interval 6-10. It is found in [2] that the window size of 5 is able to deliberate meaningful real-time QTc trend information. It also served our purposes of observing for are stable QTc and unstable QTc; namely QTc prolonging and shortening; Fig 5. At this stage, using this method, it is still unable to

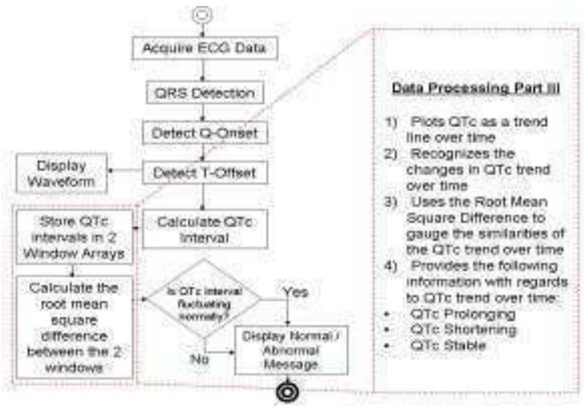

Figure 5. Explanation of Data Processing III, formulation of QTc trend, with Detailed Process Flow Diagram

differentiate between the 2 types abnormal QT intervals.

During each trend comparison a value that measures the similarity or dissimilarity of the trend would be obtained. The root mean square successive difference (RMSSD) is used to obtain such a value in the 2 comparing windows.

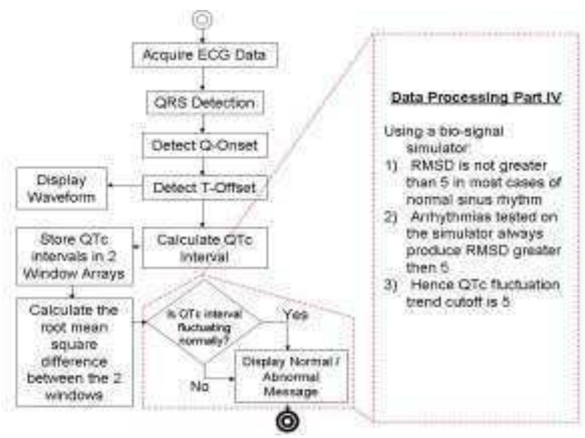

Figure 6. Explanation of Explanation of Data Processing IV, analysis of QTc trend over time, with Detailed Process Flow Diagram

After the RMSSD is derived, it is checked if it is fluctuating within the normal bounds [2]; Fig 6. If it is not, an alert is set off and the relevant parties are informed of this situation. The alert can also be seen by the patient on the mobile phone that is being used for this monitoring.

It is mentioned earlier that this embedded application is unable to differentiate between the 2 types of abnormal QT syndrome. This is where [1] has a very important role to play. Once the relevant parties are alerted of the abnormality's occurrence, all the Electrocardiography data (ECG) that was previously received and processed on the mobile phone is also forwarded in synchronization with the alerts. This is to allow for the relevant authorities to verify abnormality and also to provide the medical authorities pre-admittance biological information and to prepare all required hospital admittance administrations for the patients. This will inevitably speed up the process of the patient receiving medical attention.

3. Experiments and results

The experiments conducted dealt with the feasibility of using Q2 in daily life. The experiments were conducted on a group of people with no history of LQTS or were ever suspect of LQTS. Currently, there is no testing kit or application that is able to detect LQTS immediately. Hence, even in the hospital it is a series of succinct tests and observations before a patient can be diagnose for LQTS or even suspect of LQTS. The experiments, no doubt, at this moment cannot confirm the workability of Q2 on people; it confirms LQTS on simulated data. However, through the experiments it is able to confirm that it does not give off false positives.

The experiment environment is an administrative office. It is the place that most people in their daily lives would be at and also scientifically proven that such a sedentary work environment is a contributing factor of cardiovascular diseases [9]; especially when it is further aggravated by a lack of physical activity [10].

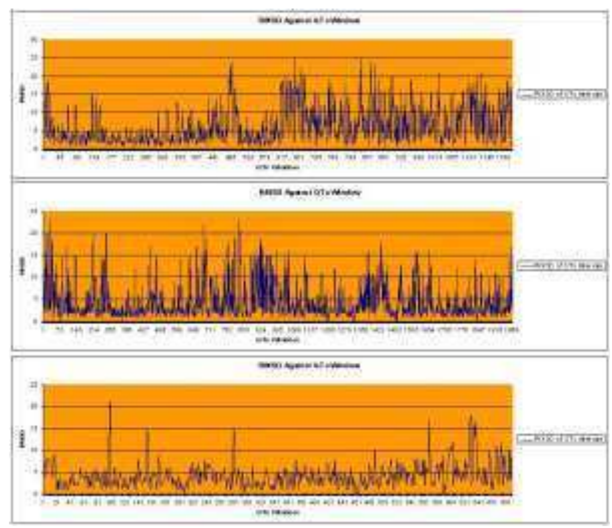
Figure 7. RMSSD trend of 3 male test subjects

During the whole experiment the RMSSD is continuously being calculated on the cellular phone to prove that QTc intervals trend monitoring is possible on. Concurrently, the calculated data is forwarded out, via the mobile internet, onto a central server for observation by our experiment monitoring team. The experiments were conducted for 2 hours per participant during 9am - 12pm.

The feasibility experiment was also extended to include sleep monitoring; Fig 8. The participants would wear the ECG monitors during their sleep and Q2 would be running on the mobile phone to continuously received and process the data.

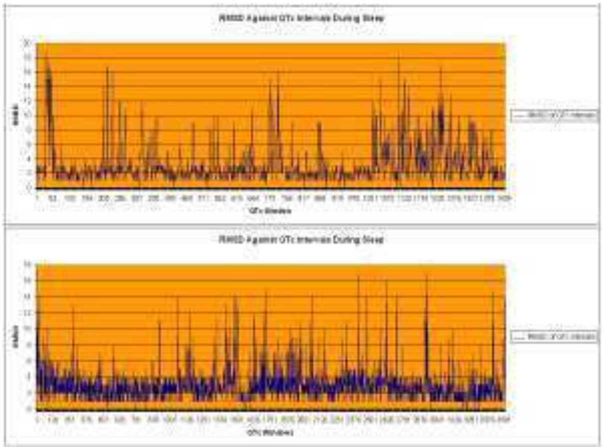

Figure 8. RMSSD Trend of male subject in experiment extension

After each experiment, the data collected was verified and each participant was asked on questions with regards to comfort, hindrance, additional effort to bring the prototype and ease of use.

The data was verified and also the data on the server was verified for transmission. All received ECG data on the server side were for other cardiac disease detection already implemented in MobiCare [1]. The participants expressed an initial discomfort of wearing the sensor. They were using a chest strap consisting of dry electrodes and the ECG sensor together with the mobile phone. After the initial discomfort, all participants expressed they just forgot about it as they went about their daily activities. None of the participants expressed that Q2 was hindering them in their daily activities and since they were wearing the chest strap throughout the experiments and were already used to carrying mobile phones wherever they go, there was no additional effort required to use Q2. Overall, the feasibility study for the usage of Q2 is a success. However, more human factors research is required to make this mobile application more use-friendly and easy to use; especially to the elderly who may not be so technologically savvy as the participants

4. Conclusion

A portable prototype to detect LQTS has been developed; Fig 9. It can be embedded on a windows mobile operated phone. It has demonstrated, with the help of a third party ECG sensor, that QTc intervals trend pattern recognition is viable in providing meaningful information. It helps in receiving meaningful information with regards to QT/QTc intervals trend patterns. It will hasten the analysis and provide an immediate physiological response with regards to the effects of outpatient treatment. Medical authorities are empowered to respond immediately if the outpatients were to exhibit any abnormal QT/QTc intervals trend patterns. For future works, other forms of pattern analysis techniques would be tested. And we also intend to introduce Q2 to our partnering hospital for testing on patients with LQTS or suspect LQTS. This will provide valuable information on how Q2 can be better improved on detecting LQTS.

Figure 9. Q2 on HTC Touch Pro displaying normal and abnormal QTc Trend detection

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