

Fully Automated Computer Measurement of QT Interval from the 12-Lead Electrocardiogram

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Abstract

The aim was to develop a fully automatic QT interval measurement algorithm for the 2006 PhysioNet/Computers in Cardiology Challenge.

The algorithm determined the Q onset and T offset points from the average beat in each lead. The QT interval measurement was calculated from the median Q onset and T offset points. Manual measurements were also made.

The mean (sd) difference between automatic and reference measurements was -49 (38) ms and between manual and reference measurements was -6 (48) ms.

1. Introduction

QT interval represents a measure of the ventricular repolarisation phase of the cardiac cycle. It is an important clinical measurement because abnormal repolarisation is indicative of susceptibility to the development of fatal arrhythmia. Manual QT interval measurement is subject to inter-observer variability, primarily due to the difficulty of determining the T wave end. Our aim was to develop a fully automated QT interval measurement algorithm and to compare these with manual measurements. The study was undertaken as part of the 2006 PhysioNet/Computers in Cardiology Challenge [1].

2. Methods

QT interval is a highly variable measurement. Heart rate, ECG lead and artifact are known to affect the measurement. Our approach was to obtain a single QT interval measurement for each recording as the median value from QT interval measurements across the 12-leads. The QT interval for each lead was determined by computer analysis of a single beat. These beats were derived from the average of beats with similar inter-beat interval from ECG recordings of 30 s length. Figure 1 illustrates the methods used.

2.1. QRS detection & RR interval measurement

For QRS detection, ECGs were bandpass filtered (0.5 – 100 Hz 4th order zero phase filter). Principal Component Analysis was applied to the filtered ECG and QRS detection performed on the first principal component (PC). The first PC always contained the largest proportion of the variability in the ECG which was dominated by the QRS complex in all subjects. This technique ensures that the QRS detection algorithm is always operating on a signal with maximum ventricular component and eliminates the requirement to select a specific lead for QRS detection. QRS time points were detected as instances of peak amplitude above an amplitude dependent threshold of the differentiated PC signal. The mean RR interval was calculated over the entire recording.

2.2. Calculating the average beat in each lead

All beats with an RR interval falling within 10% of the mean RR interval of the ECG were used to calculate the average beat. Averaging was done after time aligning the beats using correlation to find the optimum alignment (illustrated in figure 1).

2.3. Determining Q onset

Our algorithm exploited the relatively quiescent interval immediately before ventricular depolarisation. Q onset in each lead was determined by finding, within a 200 ms interval before the R peak, the point at which the amplitude range within a 30 ms sliding window fell to its minimum.

2.4. Determining T offset

T wave end in each lead was determined by mathematically modeling the end stage of repolarisation using a 2nd degree polynomial. T wave peak was

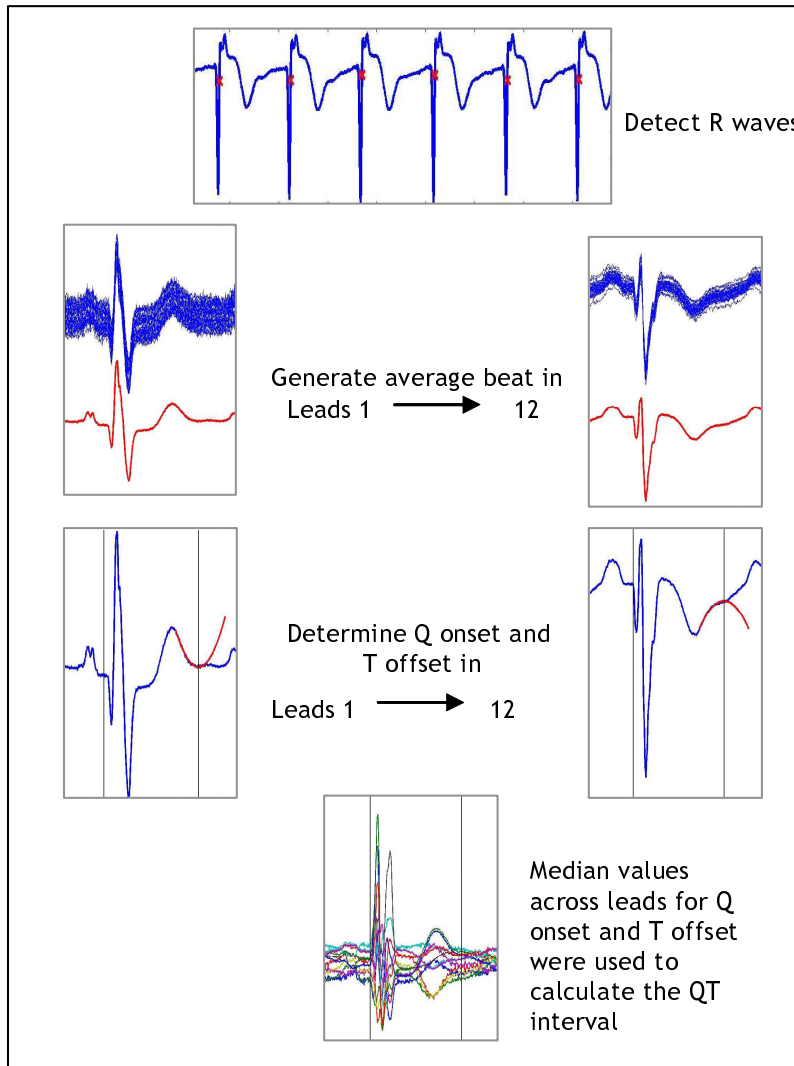


Figure 1. Illustration of methods.

identified and the 150 ms interval following this peak was optimally fitted with the 2nd degree polynomial using the Matlab 'polyfit' command. The point of inflection on this curve identified the T wave end point (illustrated in figure 1).

2.5. QT interval measurement

We anticipated that by exploiting the inherent redundancy in the 12-lead ECG with respect to QT interval measurement that our algorithm would be robust against outlying measurements, for example in low amplitude or noisy leads. So rather than measure the QT interval in a specific lead we chose to measure the QT interval in all leads and use a representative value from these measurements. The median Q onset and T offset points from the 12 individual measurements were used to

calculate the QT interval measurement for each ECG.

2.6. Manual QT interval measurement

QT intervals were also measured manually. These consisted of a single measurement in lead II of the ECG. Measurements were not taken where the observer could not identify a T wave end point with sufficient confidence. An error in the default setup of our manual QT measurement software meant that these measurements were taken with a resolution of only 10 ms.

2.7. Measurement analysis

Both automatic and manual measurements were compared to the Challenge reference measurements by

Bland-Altman analysis.

3. Results

Figure 2 shows the Bland-Altman plots for automatic and manual measurements against reference measurements. The automatic algorithm was able to measure all but one of the ECGs (99.8%). Manual measurements gave results in 93.3% of ECGs.

A selection of results obtained from the automatic algorithm is shown in figure 3. These were chosen because they illustrate a range of errors (large overestimation through to large underestimation) with respect to the reference QT intervals. The mean (sd) difference between automatic and reference measurements was -49 (38) ms and between manual and reference measurements was -6 (48) ms.

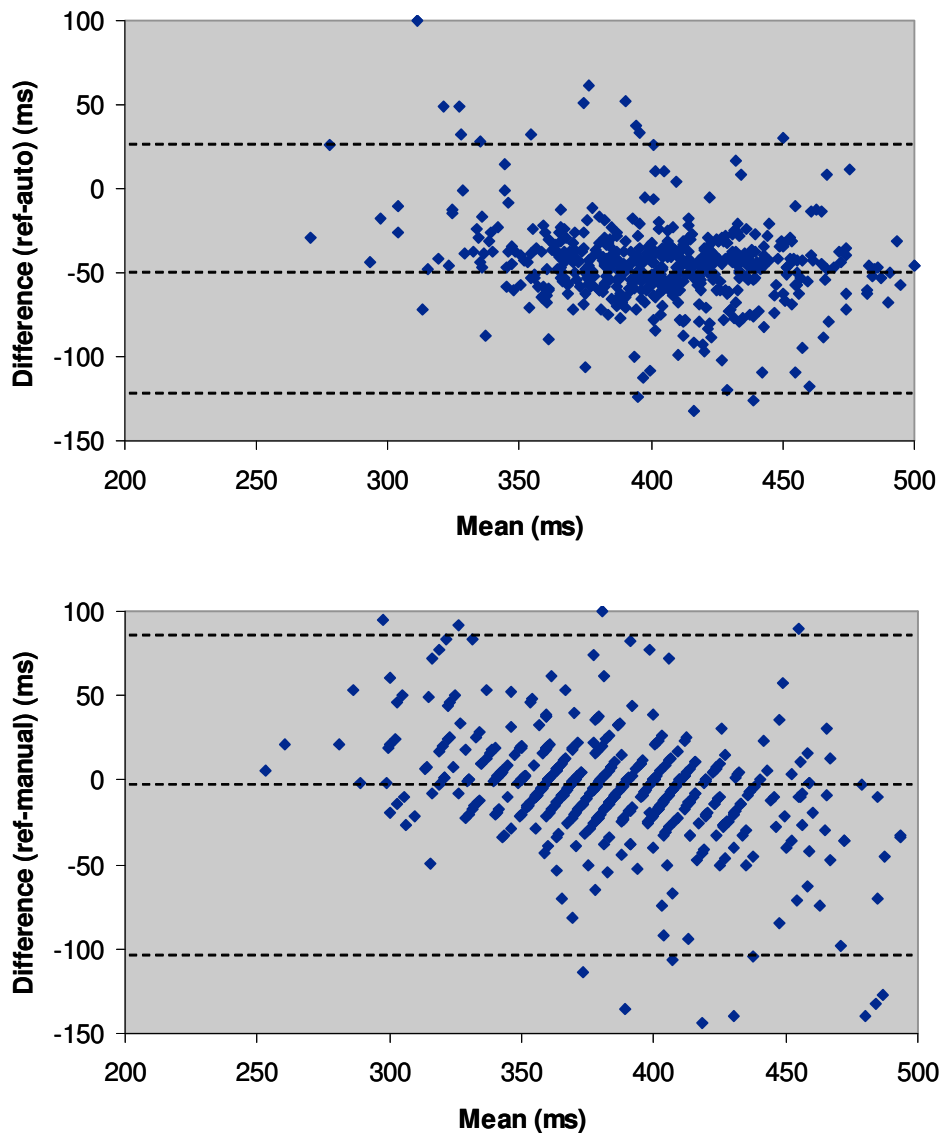
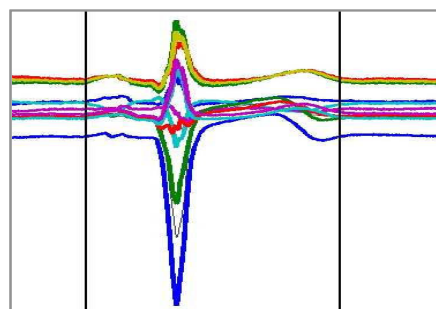
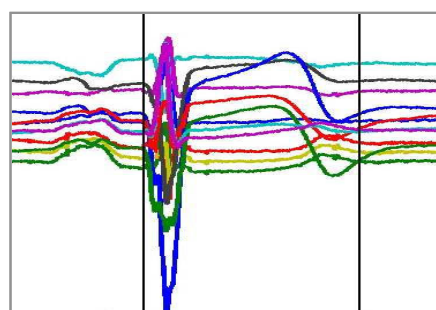


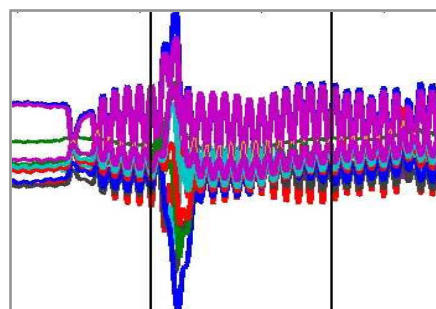
Figure 2. Bland-Altman plots for automatic (top) and manual (bottom) measurements against reference QT intervals.



Error = -100 ms
(patient042/s0137lre)



Error = -1 ms
(patient032/s0102lre)



Error = +48 ms
(patient015/s0047lre)

Figure 3. A selection of automated QT measurements.

4. Discussion and conclusions

The automatic measurements show an overall bias of approximately 50 ms overestimation in QT interval compared with reference values. This compares with a bias of approximately 6 ms overestimation for our manual measurements. However, the automatic measurements

have less variability about the mean value than our manual measurements with standard deviations of the difference between measured and reference values of 38 ms and 48 ms respectively. Subtracting the mean overestimation value from the automatic QT interval measurements would provide a simple calibration method for this algorithm. From our previous experience with this T wave end detection algorithm we expected a much lower overestimation of the QT interval [2, 3]. It is apparent however that errors in Q onset detection are contributing to the overestimation of QT interval in the automatic algorithm as illustrated in figure 3 top panel. The middle panel of figure 3 illustrates an example of good agreement between our algorithm and reference measurement with an error of only -1 ms. However, the panel shows clearly that repolarisation continues past the measured T offset point in a minority of leads and raises the question of whether QT interval measurement should be confined to a single lead. The lower panel of figure 3 shows that the algorithm is robust against leads with much noise. It would be informative to analyse the specific Q onset and T offset points from the Challenge entries to determine the most accurate algorithms for these respective measurements. Once established it would then be possible to mix and match these algorithms to improve the overall performance of the automatic algorithms.

Acknowledgements

PL and STK are supported by grant funding from the EPSRC.

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