Identifying and Measuring Representative QT Intervals in Predominantly Non-Normal ECGs

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Abstract

Background: *Computers in Cardiology Challenge 2006 has the objective to optimally assess the QT interval measurements for 549 ECGs. The challenge poses two problems: 1) the identification of representative normal beats and 2) accurate determination of the QT interval for these single beats.*

Method: *All QT intervals and other relevant information for the 549 ECGs have been annotated by a combination of independent standard algorithms. An inclusion ellipse has been constructed around the centroid of the Poincaré Plot using quasi-robust estimation. The first beat in time sequence view covered by the ellipse was annotated for Q and Tend in lead II.*

Results: *544 out of all 549 ECGs could be evaluated for QT in lead II. The QT values summarize to a mean value of 366.9 ms (median 366 ms) and a standard deviation (SD) of 49.6 ms with a range between 236 ms and 569 ms, the RR mean was 831 ms (median 807 ms) with a range from 368 ms to 1804 ms and a SD of 191 ms.*

1. Introduction

The Physionet/CinC Challenge 2006 has the objective to optimally assess the QT interval measurements for 549 ECGs contributed by the PTB database. About 80% of the ECGs originate from diseased persons. The challenge poses two problems: 1) the identification of representative normal beats and 2) accurate determination of the QT interval for these single beats.

The selection of normal sinus heartbeats has been investigated to a great extent by papers on heart rate variability. These methods usually assume ECG recordings of 10 minutes or more. Since most recording durations in the challenge ECGs fall below 2 minutes, known methods selecting representative sinus beats developed do not perform satisfactorily with the CinC Challenge. Due many ECGs from diseased persons with an abundance of ectopic beats, the requirement for the algorithm is robustness to a high percentage of extreme values in the Poincaré Plot.

The Poincaré Plot, which is arrow-shaped for healthy subjects, is the graphical representation of two consecutive beat intervals, RR and RR+1, and exhibits an increasing variance for the larger RR values.

Most of the challenge's ECGs include less than 150 beats, thus the shape of the distribution of representative possible sinus beats in the Poincaré Plot is hard to determine. Therefore it is assumed to be elliptic.

A robust algorithm, capable of deriving a selection ellipse using a small number of possible sinus beats, has been developed in order to efficiently solve task 1 of the challenge. A robust version of QT estimation is proposed for task 2.

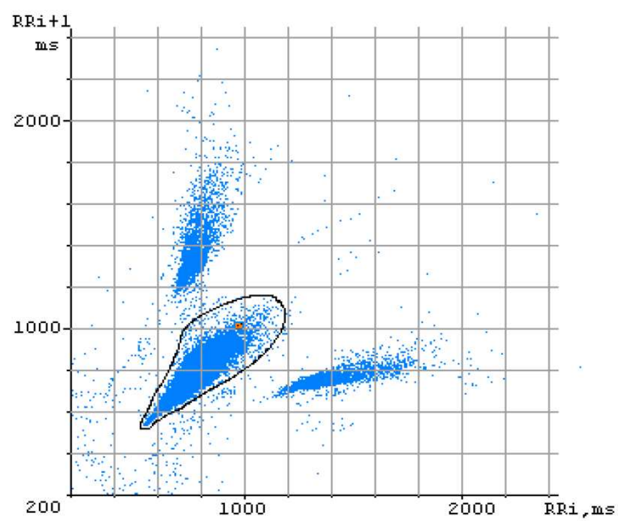

Fig 1. Illustration, how "sinus beats" are selected on the basis of long ECG recordings. "Possible sinus rhythm area at Poincaré Plot [selected] by hand" Figure and quotation from [3].

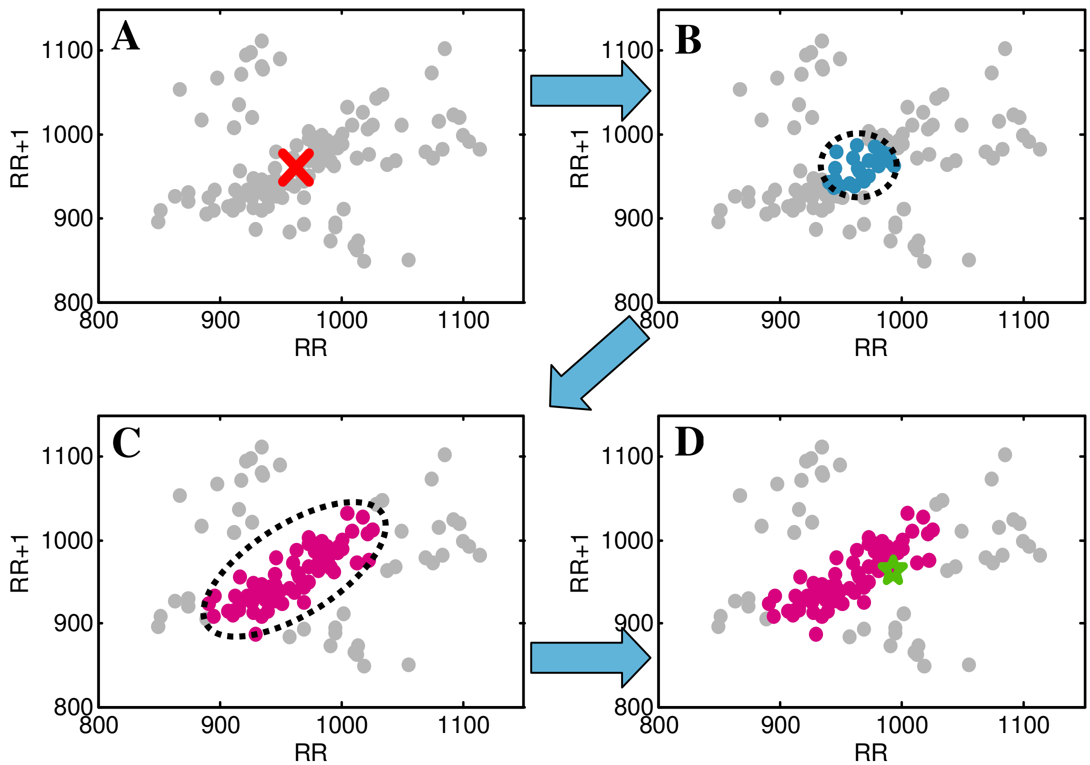

Fig. 2 Illustration of selection algorithm. A) the centroid of the Poincaré Plot. B) The 20% points closest to the centroid are used to get an estimate for the tSD. (c) A restricted population ellipse is constructed using the tSD. D) the first observation (in the time sequence) covered by the restricted population ellipse is used for QT evaluations.

2. Methods

Selection of a representative beat

The starting point for the selection of a representative normal beat is the Poincaré Plot, where the inter-beat interval has been derived from the Frank leads using an established method [1]. The interval before the beat under investigation is called RR and the interval after is called RR+1.

Assuming the majority of the beats to be representative, the median of the points in the Poincaré Plot has been chosen as a centroid. It should lie in the vicinity of the representative normal beats. As we are looking for the first beat similar to the representative centroid beat, an ellipse containing the cluster of representative beats has been constructed. Normally a Poincaré Plot is arrowhead-shaped, but the small data sets provided for the challenge do not allow meaningful shape-estimation. Therefore the shape has been approximated by an ellipse.

In order to derive a quasi-robust estimate of the ellipse's covariance matrix, 20% out of all points, having the smallest Euclidian distance to the centroid, are selected. Where the Euclidian distance between a point **x** and the centroid **m** is defined as:

$$d(x,m) = \sum_i (x_i - m_i)^2$$

The truncated standard deviation (tSD) of these selected points is used to construct the covariance matrix **W**. The matrix is constructed using the Eigenvectors (-1/√2,1/√2) and (1/√2,1/√2) with the empirically derived Eigenvalues 3 and 12 times tSD. The covariance matrix then is the solution to the linear system:

$$W\begin{pmatrix}-1\\1\end{pmatrix}=3\cdot tSD\begin{pmatrix}-1\\1\end{pmatrix} \quad \text{and} \quad W\begin{pmatrix}1\\1\end{pmatrix}=12\cdot tSD\begin{pmatrix}1\\1\end{pmatrix}$$

Using the covariance matrix, the Mahalanobis distance of the points **x** in the Poincaré Plot to the centroid **m** is calculated as:

$$d(x,m)=(x-m)W(x-m)^T$$

The cutoff value for the Mahalanobis distance has been set to 12. The points covered by the selection ellipse are then used for the QT analysis.

Measurement of Q and T wave

The Q wave as the beginning of the QRS complex has been detected using the multimodal morphology derivative (MMD) described in [4].

Determining the end of the T wave is a complex task due to the large variance in the morphology of the T wave in diseased subjects. Therefore, we implemented a combination of four independent annotation algorithms [2,4]:

a) Position where the potential reaches 5% of Tmax amplitude
b) Interception of the first differential of the T wave with respect to time with the zero isoelectric line
c) Intercept of the line tangential to the point of maximum T wave down-slope with the isoelectric line
d) Maximum of the MMD transformed signal after Tmax

where Tmax denotes the maximum of the T wave aptitude.

As a first step, three Tend annotations (a, b and c) are combined by a weighted mean. In order to derive the weights, the annotations are sorted by value. We denote the smallest distance to R with T_1 and the largest distance with T_3. The weighted mean is calculated as

$$T_W=\frac{T_2-T_3}{T_3-T_1}T_1+\frac{T_1-T_2}{T_3-T_1}T_2$$

The weighted mean implements a majority rule, which favors the Tend annotation with another annotation in its vicinity. This method is inspired by the idea that if two independent measurements of same strength derive similar annotations they are more likely to be correct than an annotation derived by just one single method.

As a second step, the weighted mean T_W is compared to the MMD derived T_{MMD}. The final value for Tend is the minimum of T_W and T_{MMD}.

3. Results

All calculations were done using Matlab R14SP3 and the Abbott Biosignal System (ABBIOS).

The median (mean) of the relative amount of beats left in the analysis is 0.91 (0.87) with a standard deviation of 0.14. Mind that this calculation includes the five ECGs removed from analysis with a drop out ratio of 1.

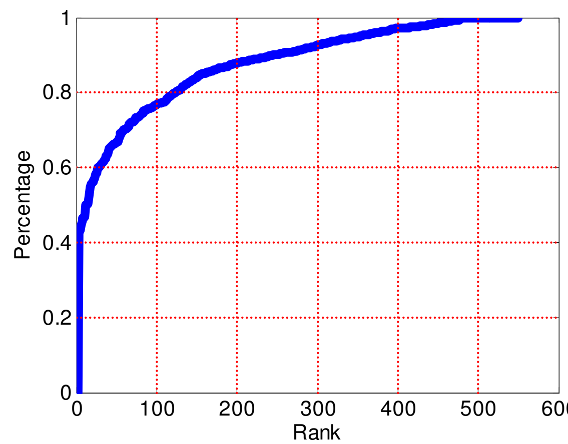

Fig 3. Distribution of percent beats included in analysis (rank ordered).

QT intervals have been calculated for 544 ECGs. Five ECGs had to be excluded due to very bad signal quality and severe morphology deviation from sinus beats. The measured QT intervals have a median (mean) value 366 (366.9) with a range of 236 to 569 and a standard deviation of 49.6.

The score for the CinC Challenge 2006 is 40.

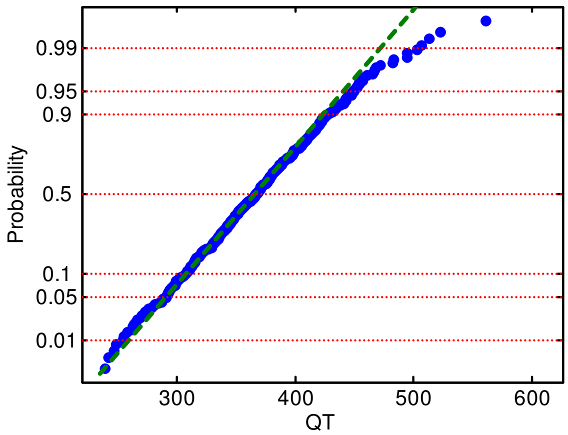

Fig 4. Probability plot of the QT values

The mean of the RR intervals was 831 ms (median 807 ms) with a range from 368 ms to 1804 ms and a SD of 191 ms.

4. Discussion and conclusions

The scope of this poster has been the reliable determination of representative normal sinus beats, and the robust estimation of Tend.

We present an algorithm for robust estimation based on the Poincaré Plot, using a centroid-focused ellipse to estimate the area of expectation for potential sinus beats within sparse data sets. The method reliably identified representative sinus beats on a per ECG level.

A first supposedly normal beat could be identified in 544 out of 549 ECGs (99.1%), with QT values in the range of 236 ms to 569 ms and a median QT of 3666 ms.

An overall score of 44 could be achieved in the challenge competition.

References

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