A Study On the Beat-To-Beat QT Interval Measurement

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Abstract

ECG analysis is main techniques for diagnosing heart disease. In recent, some studies have been performed about detection of QT interval. But, it's difficult to detect QT interval because T wave is evasive. In this paper, we have detected peak point and end point of T wave and calculated QT interval. And the result has been compared with the other algorithm after detection of QT interval.

Introduction

Q point and T point must be detected accurately to calculate QT interval. Because the frequency of R wave is mainly high, R peak detection is not difficult even with noise. Therefore there are many algorithms about R wave detection. But T wave detection with noise is difficult because it has low frequency component and therefore there are not accurate detection algorithms. Further more, detection of T end point is very difficult in Holter ECG data, not in resting state data.

In this paper, we show an algorithm that use derivative and low-pass filtered ECG signal and morphology of each T-wave, and compare its performance with that of other algorithms

Method

Generally detection points in T wave are peak point(Tp) and end point(Te). We detect two point and calculate two QT intervals(QTp, QTe). The procedure of calculating QT interval is as follows.

1. R peak point detection

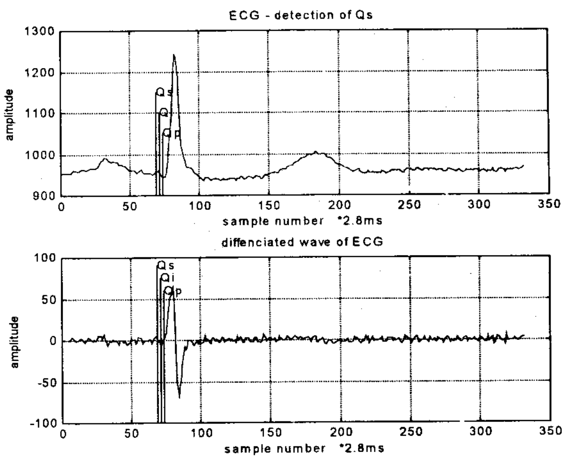
   First, we use the R peak detection algorithm(by Pan and Tompkins, 1985) to detect R peak. This algorithm has 6 steps as follows:

   low-pass filtering, differentiation, squaring, moving window, integral(140ms), adaptive threshold.

2. Q peak point(Qp) and QRS starting point(Qs)

   Second, we search Qp backwards from Rp. In the differentiated ECG signal d(k), Qp is defined at first backward zero-crossing point from Rp. But, we think that the Q wave is not present when the distance between Qp and Rp exceeds 80ms.

   Qs(QRS starting point) is defined as the beginning of Q wave or R wave(if Q wave is not present). (by P. Laguna, 1990) We search Qi that is defined as the point has maximum slope using backward searching from Qp in d(k). Then, Qs is defined as the point that meets threshold Hq, d(Qi)/2, backward. Similarly, we search Ri has maximum slope in d(k) when Q wave is not present. And in that case, threshold,Hq, is applied as d(Ri)/5.



<Figure.1> Detection of Qp,Qi,Qs

3. T wave detection

   T wave has 4 different kinds in differentiated signal:
   1)normal T-wave(upward-downward),
   2)inverted T-wave(downward-upward),
   3)only-downward T-wave,
   4)only-upward T-wave

   We search maximum(Tmax) and minimum(Tmin) point in f(k) preprocessed from d(k) by low-pass filter at cut-off frequency, 20Hz, using window has two limits(start, end point) forward from Rp. It has several steps as follows to detect Tp, Te.

a. If d(Tmax)<d(Tmin), then 1) or 4).
a-1. If |Tmax|>4|Tmin|, then 4)
a-2. Else 1).
b. If d(Tmax)>d(Tmin), then search Tmina is defined as minimum point in d(k) backward from d(Tmax).
b-1. If |Tmax|<4|Tmina|, then 1).
b-2. If |Tmin|>4|Tmax|, then 3).
b-3. Else 2).

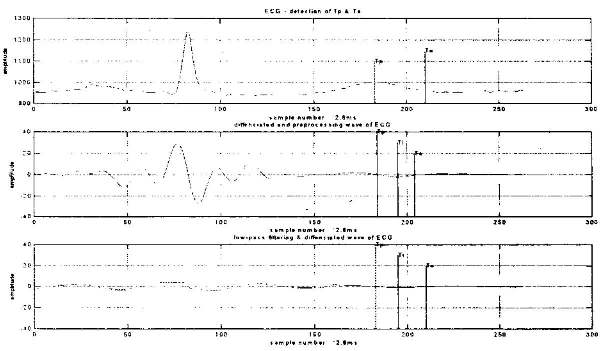
Now, we search Tp and Te using Tmax, Tmin and the shape of T wave(case 1-4). In each case, we define Ti as the last sufficiently large point(Tmin or Tmax or Tmina). From Ti, Tp is defined as the first zero crossing point in f(k) backward. Next, Te is defined as the point meets threshold Ht, f(Ti)/4 forward from Ti.

Modified Processing

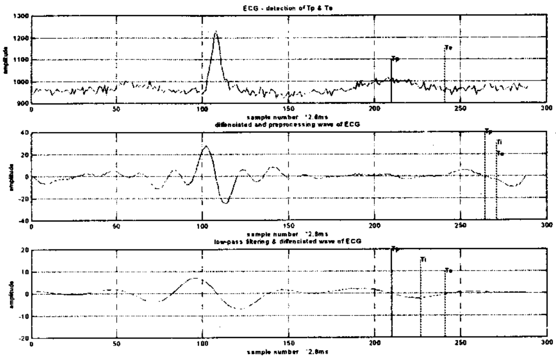
This method is not correct if noise is added. We cannot find Tp and Te from Tmax, Tmin or Tmina in f(k) in noisy signal. There are many zero-crossing and Tmax(or Tmin, Tmina) is not helpful because noise has high frequency component but T wave has only low frequency component. Therefore, we must remove high frequency noise to search correct T wave.

Of course, we have filtered d(k) using low-pass filter before R peak detection(f(k),cut-off frequency: 20Hz). But, the noise between T wave frequency (5Hz) and QRS complex frequency (20Hz), isn't removed.

Therefore, we filter original signal using low-pass filter has cut-off frequency at 5-10Hz. After Q wave is detected using original signal, the filter is used before T wave detection. This filter removes QRS complex. And this signal is used to detect Tp and Te. This method is compared with before method in Figure.2(without noise) and in Figure 3(with noise).



<Figure.2> T detection comparison without noise



<Figure.3> T detection comparison with noise

4. QT interval calculation

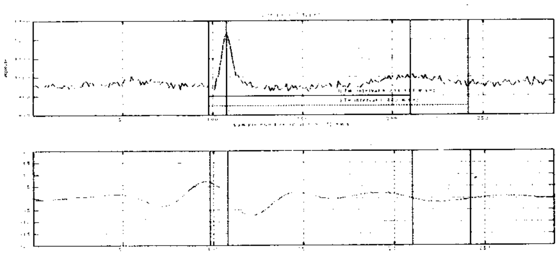
Now, we can calculate QT interval with Tp,Te and Qs. We define QTP as an interval between Qs and Tp. And we also define QTE as an interval between Qs and Te. We can calculate QTE and QTP using

QTE=Te-Qs

QTP=Tp-Qs

Result and Discussion

To calculate QT interval, we used MIT/BIH Database. Figure 3 plots ECG signal and two differentiated signal of MIT/BIH 101st. And also show the QT interval.



<Figure.3>QT interval detection

The result has been compared with the other algorithm. (Threshold, Differential Threshold, Slope Intercept, Peak Slope Intercept) And the result also has been compared with the result of manual measurements.

Reference

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