ROC Analysis of PVC Detection Algorithm using ECG and Vector-ECG Characteristics

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I. INTRODUCTION

ELECTROCARDIOGRAM (ECG) can be monitored non-invasively for long periods of time and gives us effective information on the heart condition. Especially, arrhythmia would be diagnosed by ECG. One of frequent symptoms of arrhythmia was premature ventricular contraction (PVC). PVC is found from normal people, but if it occurs frequently, it would lead to be serious. Since the pattern and axis of PVC are different from normal ECG signals definitely, PVC could be distinguished by ECG and vector ECG. ROC curve was applied to evaluate PVC detecting algorithm, which is based on ECG and VCG. ROC was one of the methods to evaluate the reliability of diagnostic check. In the study, 4 types of the PVC detecting algorithms were evaluated, parameters of which are maximum amplitude of QRS complex, width of QRS complex, r-r interval and geometric mean of VCG.

II. EXPERIMENTAL METHODS

A. Preprocessing of ECG signals

34 signals of period of 5 minutes using Lead II were analyzed by MatLab, which were based on MIT-BIH arrhythmia database. First of all, the baseline was removed by median filter to preprocess the ECG signal. R peaks were detected for ECG analysis method, and normal PVC was extracted for VCG analysis method. Four PVC detecting algorithm was analyzed by ROC curve, which parameters are maximum amplitude of QRS complex, width of QRS complex, r-r interval and geometric mean of VCG. To set cut-off value of parameters, ROC curve was estimated by true-positive rate (sensitivity) and false-positive rate. Sensitivity and false negative rate (specificity) of ROC curve calculated, and ECG was analyzed using cut-off value which was estimated from ROC curve. As a result, PVC detecting algorithm of VCG geometric mean have high availability, and PVC could be detected more accurately with amplitude and width of QRS complex.

Keywords—Vectorcardiogram (VCG), Premature Ventricular contraction (PVC), ROC (receiver operating characteristic) curve, ECG
y(nT) = \frac{1}{N} [x(nT - (N - 1)T) + x(nT - (N - 2)T + \ldots + x(nT)] \quad (5)

3. Algorithm of R-R interval
One of the significant characteristics of PVC, compensatory pause right after PVC was applied to RR interval algorithm. Once R peak was detected, the \(i^{th}\) R was defined as \(R(i)\). The parameter (RR_inter) is presented in equation (6).

\[ I(i) = R(i) - R(i-1), I(i+1) = R(i+1) - R(i) \quad (6) \]

4. PVC detection algorithm using VCG geometric average difference
The comparison of reference VCG and instant VCG can be calculated from equation (7).

\[ \text{diff}_\text{VCG} = \sqrt{(\text{ch}1 - \text{ch}_{1\text{ref}})^2 + (\text{ch}2 - \text{ch}_{2\text{ref}})^2} \quad (7) \]

Sum of reference pattern VCG and instant VCG, \(\text{Sum}_\text{diff}\) (equation (8)), was compared with the value of integrating the instant vector difference, \(\text{diff}_\text{VCG}\), to detect PVC in each ECG period

\[ \text{Sum}_\text{diff} = \sum_{n=1}^{N} \text{diff}_\text{VCG}(n) \quad (8) \]

5. ROC analysis and evaluation of PVC detecting algorithm
The threshold of signals after preprocessing was estimated to determine PVC, and the reliability of the algorithm was evaluated using ROC curve (receiver operating characteristic curve).

\[ \text{Detection rate} = \frac{\text{The number of PVC} - (FP + FN)}{\text{The number of PVC}} \quad (9) \]

\[ \text{Sensitivity} = \frac{TP}{TP + FN} \times 100 \quad (10) \]

\[ \text{Positive Predictivity} = \frac{TP}{TP + FP} \times 100 \quad (11) \]

(\(TP : \text{True Positive}, FP : \text{False Positive}, FN : \text{False Negative}\))

III. EXPERIMENTAL RESULTS
As the significant characteristic of arrhythmia was the high amplitude, the parameter was developed by using peak amplitude of QRS complex during one period. In the signal theory, a receiver operation characteristic curve, or simply ROC curve, is a graphical plot of sensitivity. In figure 2-5, how to change the sensitivity and specificity of 5-minute PVC data according to the threshold of each parameter was shown on the left, and ROC curves were shown on the right.

\[ \begin{align*}
\text{Fig. 2 The ROC analysis of detection PVC using differences of QRS maximum magnitude:} \\
\text{(a) The diff_QRS distribution according to the cut-off value, (b) ROC curve} \\
\end{align*} \]

\[ \begin{align*}
\text{Fig. 3 The ROC analysis of detection PVC using differences of QRS width :} \\
\text{(a) The QRS_width distribution according to the cut-off value, (b) ROC curve} \\
\end{align*} \]

\[ \begin{align*}
\text{Fig. 4 The ROC analysis of detection PVC using differences of R-R interval :} \\
\text{(a) The RR_inter distribution according to the cut-off value,} \\
\text{(b) ROC curve} \\
\end{align*} \]
To evaluate reliability of the PVC, the value of appropriate threshold was 22.32 in case of the algorithm using geometric mean through ROC analysis. The threshold was applied to the MIT-BIH PVC data. As a result, the total detection rate was 82.89%, and the sensitivity and specificity rates were 82.89% and 88.63% respectively. PVC detection rate was 90.53%, and the sensitivity and specificity rates were 82.89% and 82.89%, and the sensitivity was 99.52% in case of the algorithm using QRS width and amplitude.

IV. CONCLUSION

In the study, 4 types of the PVC detecting algorithms were developed, and ECG signal of MIT-BIH arrhythmia database was analyzed for evaluating the algorithm. The appropriate thresholds were set from ROC analysis to make the results more accurate.

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