Indicator of Myocardial Ischemia Based on the Mean Power of ECG Low Frequency Content: Comparison with ST Segment Trend

A Gutiérrez, G Zarco*

Centro de Investigación en Computación del IPN, Mexico City, Mexico
*Instituto Nacional de Cardiología Ignacio Chávez, Mexico City, Mexico

Abstract

In order to cause myocardial ischemia, the left anterior descending coronary artery was occluded and released two times in twelve dogs. The occlusion - release times and the ECG were recorded.

Spectral content in the range of 1 to 10 Hz was obtained by means of a digital filter. After filtering, the mean power was determined and plotted in normalized trend curves. Averaged beats were calculated, one per epoch per lead, and used to obtain ST level trend plots. The events true-occlusion, late true-occlusion, false-occlusion, true-reperfusion and false-reperfusion were defined according to the arterial status and then counted.

It was concluded that the indicator based on ECG low-frequency content can not replace the ST segment trend. However, it should be suitable to improve decision - making when an alternative therapy could be necessary.

1. Introduction

Changes to negative polarity in T wave, variations in ST level following and substituting negative T wave, morphological changes in QRS complex and arrhythmia occurrence, they all represent a sequence of electrocardiographic events involved during a coronary occlusion [1,2]. Typically, the arterial reperfusion may cause a gradual reversion to electrocardiographic basal conditions [1,2]. The use of thrombolytic agents may induce reperfusion and accelerate the return to electrocardiographic basal conditions [3].

Daily, ECG morphological changes are used to determine myocardial ischemia and the first trials to evaluate reperfusion therapies by means of ECG emerged from the application of continuous monitoring technique. Several studies have demonstrated the utility of time domain monitoring of the ST segment [3-10], QRS vector difference [4,10-13] and heart rate variability[14].

Because some problems of specificity and sensitivity remain in these continuous monitoring techniques, some other domains have been explored. At present, heart rate variability is expressed as the relationship between their low and high frequency contents [15-17]. It is pretended to improve ST segment monitoring using wavelet [18,19] and Karhunen-Loève transforms [20,21], among others. Wavelet transform has been also used to identify ECG fiducial points and patterns [22-24], but unfortunately these three studies are not related with reperfusion evaluation.

On the other hand, the variety in recording techniques used by different researchers, (including errors in bandwidth), the lacking in uniform criteria to classify ischemic changes in electrocardiogram, the diversity in agents used for reperfusion (different thrombolytic agents with or without adjuvant drugs, angioplasty and coronary bypass) and the variety in validation techniques (TIMI grade, enzymatic levels, mortality rate in different terms and ventricular ejection fraction), do not permit to find out if the added techniques indeed improve the performance of reperfusion indicators.

Considering the facts above described, an indicator of myocardial ischemia based on the mean power of ECG low frequency content was previously developed [25], and now compared with ST segment trend.

2. Method

2.1. ECG recording

In order to obtain similar records to those obtained from an infarct – thrombolysis situation, the next experiment was developed.

In twelve anesthetized and ventilated dogs (18 – 25 Kg) the left anterior descending coronary artery was occluded and released according to the Harris technique. The first occlusion lasted 5 min. A 20 min recovery period was allowed before a second occlusion was induced. This occlusion lasted from 20 to 120 min, different for each animal.

Leads II and III were obtained, as well as epicardial records in those zones where necrosis, injury, ischemia

and normal records were expected, three records per zone.

The used bandwidth was from 0 to 180 Hz. The fourteen leads were simultaneously amplified and digitized (540 samples per second, 12 bits per sample). Every 30 s, 28 s epochs were saved on a hard disk.

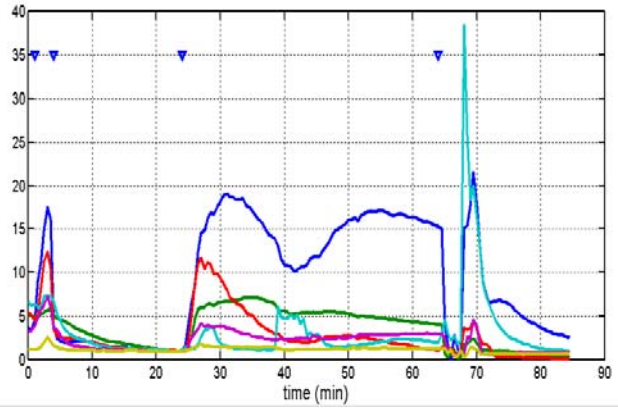

Figure 1. Normalized mean - power of ECG low frequency content. Different curves correspond to different myocardial zones. Coronary occlusions are represented by the first and third triangular marks, the second and fourth ones correspond to releases. The values just before the second occlusion were used as reference during the normalization. The sudden decrement and increment after the second release were caused by fibrillation and recorder disconnection, respectively.

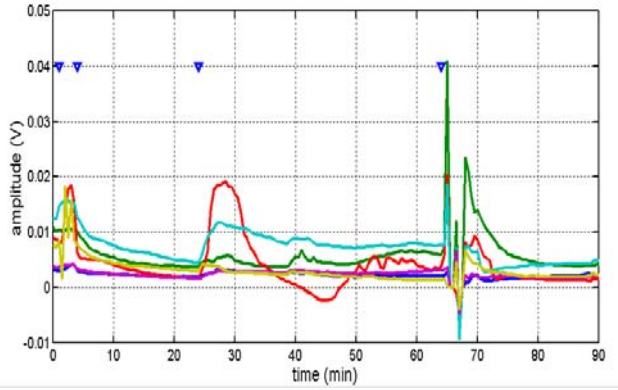

Figure 2. ST segment trend plot for the same experiment illustrated in figure 1.

2.2. ECG processing

Spectral content in the range of 1 to 10 Hz was obtained by means of a 3rd order Butterworth digital filter. Per epoch, and after filtering, the mean power was determined and plotted in normalized trend curves, see figure 1. Values in a time showing normal circulation were used as reference in normalization process.

In order to determine the ST segment trend plots, the QRS complexes were detected and classified (by means of the correlation coefficient). Using only the normal QRS complexes an averaged beat was obtained per epoch per lead. The ST level was measured 65 ms after the R wave in these beats. Figure 2 shows a ST segment trend plot.

2.3. Events definition and counting

A threshold was established for each indicator, 3 mV for ST trend and 3 for normalized ECG mean power. When the indicator value exceeded this threshold an occlusion was considered. The following events were also defined and counted:

True occlusion. An indicator exceeds the threshold two or more consecutive times (equivalent to 1 or more min of signal) while the coronary occlusion is sustained.

Late true occlusion. It is a true occlusion that exceeds the threshold 5 min after the beginning of the occlusion.

False occlusion. An indicator exceeds the threshold two or more consecutive times while the coronary artery is not occluded. It was determined only when occurred between the two experimental occlusions.

True reperfusion. After a true occlusion or a late true occlusion and the coronary release, the indicator returns to under threshold values.

False reperfusion. After a true occlusion or a late true occlusion and while the coronary occlusion is sustained the indicator returns to under threshold values.

3. Results

Two animals died before the experiment finished, therefore, the next data correspond to 10 cases.

The table 1 shows the occurrence of the occlusions and reperfusions events. The event count was made considering separately each captured lead, this because in a clinical environment usually only a few leads are available.

Table 1. Events counted for each indicator.

	ST segment trend	Mean power of ECG LF content
True occlusion	77	60
Late true occlusion	8	12
False occlusion	4	4
True reperfusion	47	48
False reperfusion	28	16

4. Discussion

Because of the experimental conditions, there are low levels of noise in the records, there is not bundle branch blocks, etc. In these conditions, the simple approach used for ST measurements results proper.

As compared with clinical values, the point selected for the ST level measurement and the ST threshold, could seem odd. They were selected for dog - epicardial records.

It was observed that the ST segment trend detected more occlusions (77 true + 8 late true against 60 + 12 of the man power), but on the other hand, it also showed more false reperfusions (28 against 16). Both indicators registered four false occlusions, all of it corresponding to the same event. It leads to think over the possibility of a true occlusion, and therefore, about the need of a direct method for the coronary flux measurement during the experiments.

When prolonged occlusions occurred (as the second one in each experiment), the mean power of ECG low frequency content showed less false reperfusions. However, some times it also diminishes when the occlusion remains for a long time, probably because of the collateral circulation.

5. Conclusions

Taking into account that the mean power of ECG low frequency content detected better the reperfusion status, it should be suitable to improve decision - making when an alternative therapy could be necessary.

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Address for correspondence.

Alfonso Gutiérrez
Centro de Investigación en Computación, IPN.
Av Juan de Dios Bátiz s/n
Col. Nueva Industrial Vallejo
México D.F. CP. 07738
México
E-mail: alfonso_gamx@yahoo.com.mx