

# ECG Mean-Power as Primary Indicator of Myocardial Ischemia

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## Abstract

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

*Using an epicardial lead in the necrosis zone for each dog, spectrograms were obtained. The spectrograms showed great changes related to the perfusion status in the low and high frequency regions. As a numerical indicator, for each recorded lead, the normalized mean-power was calculated for both the low frequency region (1 -10 Hz) and the high frequency region (30 -100 Hz).*

*As a cardiac ischemia indicator, the normalized mean-power of the low-frequency region (LFMP) plot was obtained. When the coronary occlusion begins and it remains, the graphic shows an increase in the LFMP, whereas coronary releasing causes the recovery of the initial LFMP level.*

## 1. Introduction

Changes to negative polarity in T-wave, presence of changes in ST-level following and substituting negative T-wave, morphological variations 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 evoke a gradual reversion to electrocardiographic basal conditions [1,2]. The use of thrombotic agents may produce 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 treated. 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.

In the other hand, due to a variety in recording techniques used by some researchers, (including errors of bandwidth), a lacking in uniform criteria to classify ischemic changes in electrocardiogram, a variety in agents used for reperfusion (different thrombotic agents with or without adjuvants, angioplasty and aortocoronary 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, that more complex techniques implies more cost and that a viable clinic indicator is necessary, it was searched for an indicator that does not need to locate waves or segments in ECG.

## 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 five anesthetized and ventilated dogs (18 - 25 Kg) the left anterior descending coronary artery (LAD) was occluded and released according to the Harris technique. The first occlusion lasted 7 min or less if severe arrhythmias were observed. A 20 min recovery period was allowed before a second occlusion was induced. This occlusion lasted from 20 to 60 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, two records per zone.

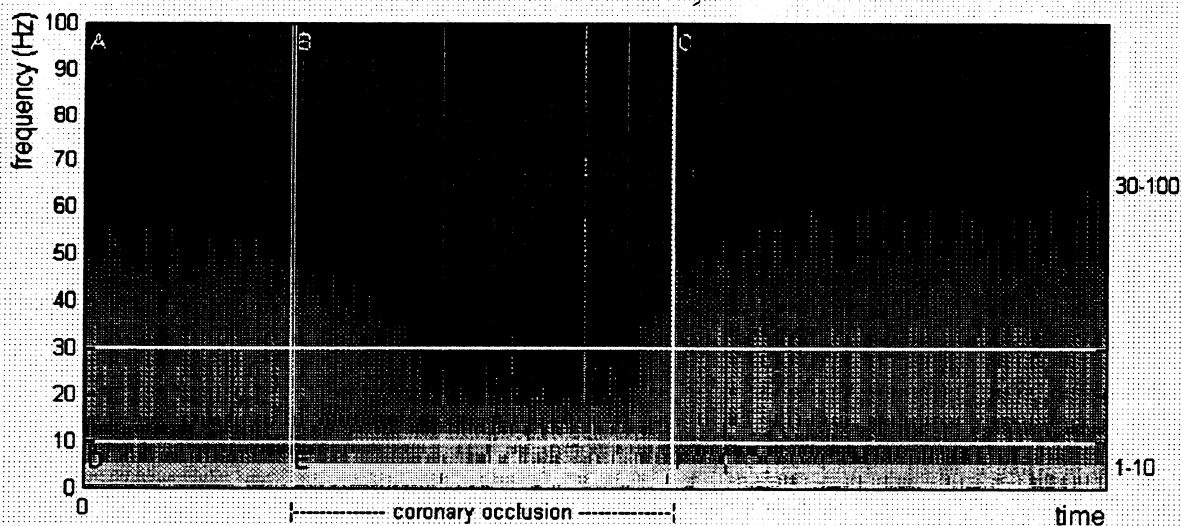


Figure 1. ECG spectrogram, the register was obtained before, during and after coronary occlusion.

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

## 2.2. ECG analysis

The spectrogram of an epicardial lead on necrosis zone was obtained for each animal, the epochs were attached to form a vector ignoring the absent 2 s segments. The spectral content was obtained every 256 samples, using a Hanning window and avoiding overlap.

The spectrograms indicated changes related to arterial perfusion on low and high frequency regions, from 1 to 10 Hz and from 30 to 100 Hz respectively. In order to obtain a numerical marker based on these changes, the trend of the mean low frequency power (1 to 10 Hz) was calculated. The low-frequency mean-power (LFMP) was normalized regarding with that obtained from the previous epoch to the arterial obstruction. The low frequency content was obtained by means of a Butterworth bandpass filter (first order, 1 and 10 Hz cut off frequencies, bidirectional filtering). The trend curves were updated every 30 s, using the entire epoch.

A similar procedure was carried out for the high frequency region (30 to 100 Hz). Finally, the ratio between the mean powers of both regions was determined.

## 3. Results

As figure 1 shows, it was observed that the ECG

spectral content seems to move towards low frequency region during coronary occlusion. That is:

- Before occlusion, certain contents of high (A) and low (D) frequencies were observed.
- During occlusion, whereas low frequency content increased – lighter (E), high frequency content decreased – darker (B).
- After coronary release the spectral contents returns to their original states (C and F).

Figure 2 shows a trend plot of the low-frequency mean-power (LFMP). From left to right the markers represent: first occlusion, release, second occlusion and release. For this plot, records showing an increase of the power proportional to the expected injury degree were selected, higher for necrosis zone and lower for ischemia one. The valley and the peak, after second occlusion, correspond with fibrillation – disconnection of the ECG recorder and sinus rhythm recovery respectively.

First occlusion behaviour was similarly observed in the five dogs. Two of them suffered ventricular fibrillation after the first release, consequently, the entire experiment was only performed in three animals. When it was possible, the second occlusion – release event also showed an increment in the LFMP followed by the return to initial levels. Finally, a non expected LFMP peak after the first release was observed in a dog.

For the necrosis records, the LFMP increment was at least five times and began in the epoch following the occlusion.

The high-frequency mean-power (HFMP) was reduced at least 80 % in necrosis leads, however in some ischemic leads the HFMP increased.

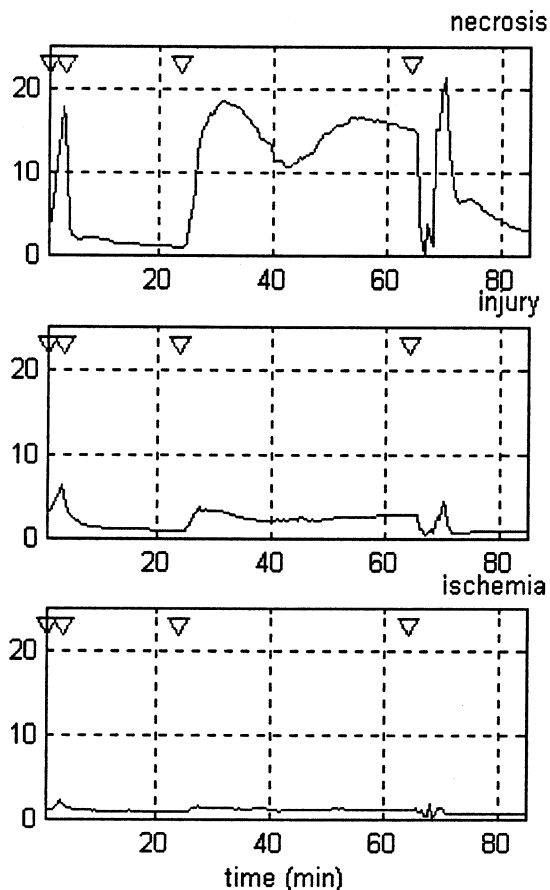


Figure 2. Trend of low-frequency mean-power obtained for electrodes placed in zones where necrosis, injury and ischemia were expected.

#### 4. Discussion

- It was mentioned that the low-frequency mean-power (LFMP) increased at least five times during coronary occlusion. The LFMP increased more than 15 times in four experiments and less than 6 times in only one experiment. The smaller increment was observed in a dog with a heart rate around of 120 bpm, whereas the frequency for the other animals was around 200 bpm. Consequently, a depending frequency correction could be necessary.

- For different leads, it was observed that the LFMP reached different maximum values and it started to increase with different time (figure 3). Thus arisen the next hypothesis: The direct relationship obtained between the maximum power value reached and myocardial state could classify the latter as necrosis, injury or ischemia. Since there is a direct relationship between the occlusion time and the infarction size, the observed delays in the increment of LFMP at different leads could be used to determine if the infarction is growing.

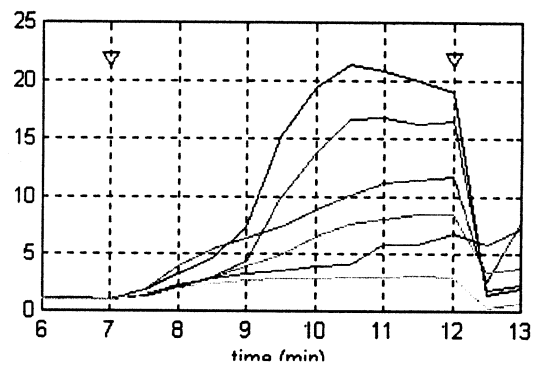


Figure 3. In this plot it is possible to observe that the LFMP begins its increment at different time for each lead. The first triangular mark corresponds to occlusion, the second one corresponds to release.

- High-frequency mean-power, as well as, the ratio between low and high frequency contents were rejected as ischemia indicators because HFMP increments were observed during occlusion periods for some isolated leads. These increments could suggest that a redefinition of low and high frequency bands is necessary. However the information in the defined low frequency band seems to be sufficient.

- More experiments are required in order to determine a quantitative relationship between ECG low-frequency mean power and myocardial ischemia. This could imply to obtain a simple indicator that could work even in presence of electromyographic and power line interference.

#### 5. Conclusion

A qualitative relationship between the myocardial ischemia and the mean-power of the ECG low frequency region was observed. In order to determine the sensitivity and the specificity of this relationship, more experiments are necessary.

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