A Method for the Ventricular Late Potentials Detection and Characterisation Using Wavelets

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Abstract - **In this paper we present a method for the Ventricular Late Potentials (VLP) characterisation using the Discrete Wavelet Transform with the Daubechies wavelets and the Newland's (1993) Harmonic and Musical wavelets. The method is based on a wavelet multiresolution scheme where the energy content of the beat-by-beat ST and the TP segments of the High Resolution Electrocardiogram (HR-ECG) are compared at different resolutions. An objective figure, the *Factor of Normality* is generated for ready clinical use. These results were compared to the ones obtained with the application of the Spectrogram, and the Choi-Williams Transform, using the Spectro-Temporal Mapping, for the VLP's study. A high resolution system for the acquisition of the high resolution electrocardiogram (HR-ECG) has been set up, with amplitude and group delay error less than 1% for which a multirate technique was used. In this way we could guarantee that our data were adequate to be submitted to the time-frequency and time-scale (wavelet) analysis. The *Factor of Normality* generated by the multiresolution scheme proved to be more sensitive, in our study cases, but the method requires further clinical testing.**

I. DESCRIPTION

VLP's are small signals due to the delayed and not homogeneous propagation of the depolarisation wave through diseased ventricular tissue. They have diagnostic value as predictors of malignant arrhythmia and cardiac arrest. A number of methods have been used to detect and describe VLP's [2], [7].

In our method [1] we use a multiresolution scheme using Daubechies and Newland's Wavelets [6] [9] [10]. The energy content of the ST and the TP segments of the High-Resolution Electrocardiogram are compared to generate the Factor of Normality, FN, which is a quantitative descriptor of the VLP presence. We defined the FN for each mutiresolution level as:

$$FN = 100\left(\frac{RMS_{TP}}{RMS_{ST}}\right)^2 \%$$

The final FN is a weighted average of the individual values or the FN of the level where the larger increment occurred, depending on the 50 Hz noise level.

The advantage of this method, relies on the good degree of insensitivity of the results, relatively to the noise level and type, that is present in the HR-ECG, provided that the noise statistics keep relatively constant over the beat under analysis. The superior ability of the wavelet multiresolution analysis to detect high-frequency components in different frequency levels, is the tool of the method.

Basically, the method works by taking a noise sample in the TP interval, where cardiac electrical activity is reduced, and using it as a gauge.

Figure 1 shows the results, using the Harmonic wavelet, for the HR-ECG of a patient seven days after myocardial infarction. The FN obtained was 41%, whilst using the spectrogram [8] the FN was 58%, a significant improvement. The improvement obtained using the harmonic wavelet is larger if compared with the FN for the Choi-Williams distribution [3] [4] [5]: 68%.

For the Newland's harmonic wavelet [10] the obtained FN was 41%, similar to the above. Harmonic wavelets lead to reduced spectral *leakage* compared to the Daubechies wavelets but time resolution is about half.

A FN of 20% was obtained by using the Newland's musical wavelet, and the concatenation of twenty ST and TP segments, instead of only one, to make up for the low time resolution of the musical wavelet. The following table summarises the results.

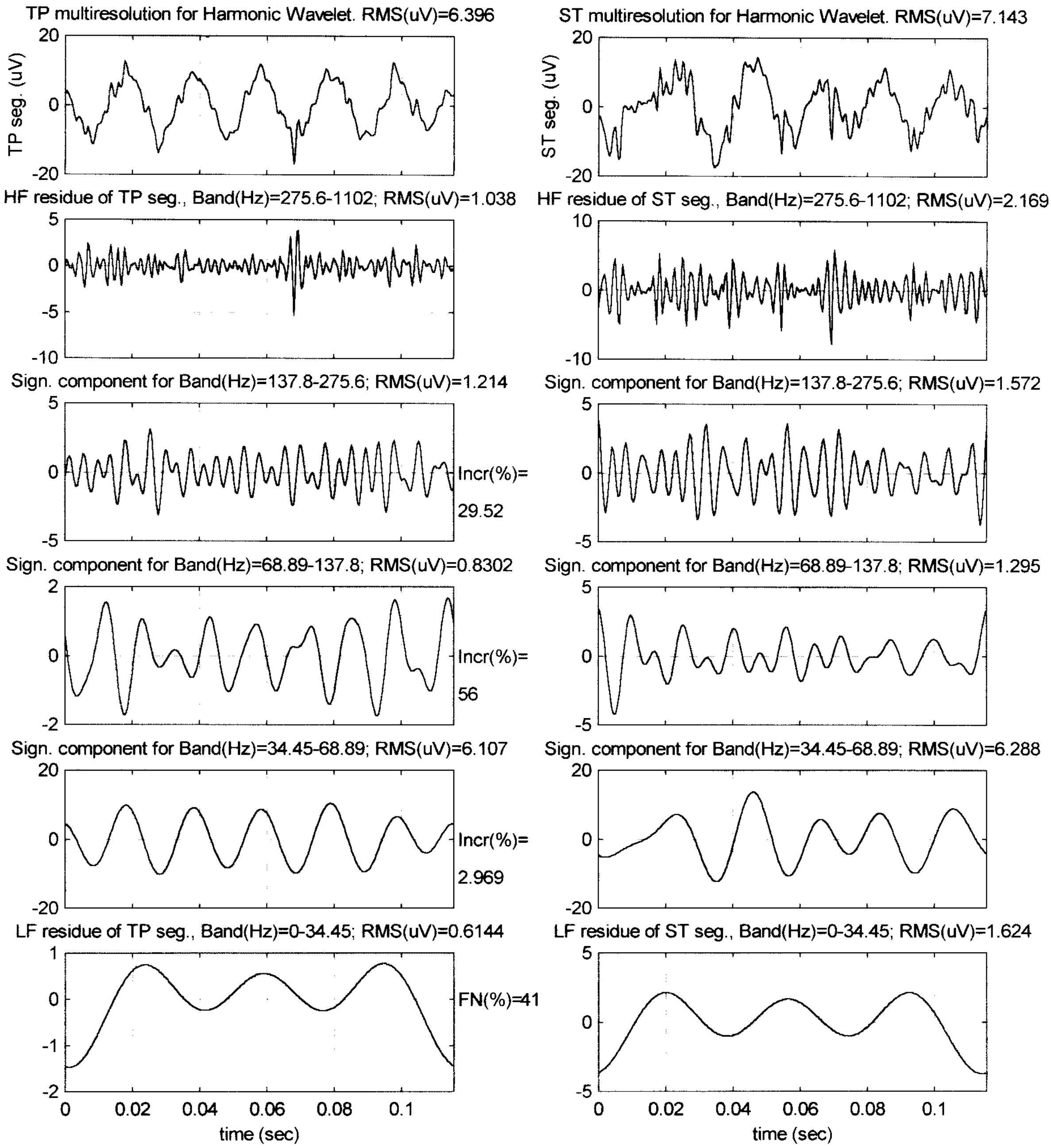

Figure 1: Multiresolution, using the Harmonic Wavelet, of the HR-ECG of a patient, seven days after myocardial infarction.

Table: Factor of Normality for a patient, seven days after myocardial infarction, using different methods.	
Time-frequency or time-scale method	*Factor of Normality*
Spectrogram (Hamming Window, 40 msec)	*58%*
Choi-Williams ($\sigma = 1$)	*68%*
Daubechies D8 Wavelet	*42%*
Harmonic Wavelet	*41%*
Musical Wavelet	*20%*

II. DISCUSSION

The multiresolution method is being tested, namely the effects of the finite duration of the time signals in the wavelet transform, and the effect of the low frequency interference, namely 50 Hz, in the FN of the low levels. We have found [1] that end effects in the low frequency reconstructed signals, from the wavelet transform, may lead to *artificial* differences in the RMS values of the ST and TP segments. This is mainly caused by the 50Hz interference phase difference between the referred segments. The RMS differences depend on the relative timing of the T wave, ST and TP segments. Although our method is less sensitive to 50 Hz interference, compared to traditional methods, it is still advisable to reduce, as much as possible, power line interference.

Concerning higher frequency interference, like muscle noise, the phase difference effect is extremely low.

The tight frequency limits of the harmonic wavelets leading to reduced spectral leakage are very appealing, compared to the Daubechies wavelets. The only problem seems to be the lower resolution of the harmonic wavelets (about half), but the overall effect of this is being tested. It should be noted that, if two ST and two TP segments are concatenated this may compensate for the lack of resolution. It seems that, generally, the results using Harmonic Wavelets and Daubechies Wavelets are similar.

The best results have been obtained for the musical wavelet, which also has tight frequency limits and much better frequency resolution. However, its very low time resolution requires a number of ST and TP segments to be concatenated, to produce a data set long enough. We have concatenated twenty ST and TP consecutive segments. Although this concatenation process might explain the better results, since a longer data set with several segments is more representative than only one segment, we have found that, in our study cases, this is not quite so. The concatenated data and the single segments produced similar FN values when the Daubechies and the Harmonic wavelets were used. This leads us to believe that, the very good frequency resolution and very low spectral *leakage* properties of the musical wavelets [10] are the major factors explaining the better FN values for the musical wavelets.

Multiresolution wavelet analysis of the concatenated segments is also a promising tool to study consecutive beat - to-beat variation of VLP's, such as alternans-type oscillations where VLP amplitude fluctuates from beat to beat.

III. ACKNOWLEDGEMENTS

The first author has received a grant from Junta Nacional de Investigação Científica e Tecnológica (JNICT): Programmes CIENCIA & PRAXIS XXI-Portugal.

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