Diastolic Heart Activity Inspection from Intracardiac Electrogram Analysis

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Abstract

Aim of this paper is to study unexpected electrical activities seldom observed during the diastolic interval of intracardiac electrograms (EGM) retrieved from patients with implantable cardioverter defibrillators (ICD).

Five patients are considered. From them 29 EGM are retrieved in different cardiac conditions: 18 immediately before ventricular tachyarrhythmia (VT-EGM) initiation, and 11 in basal heart condition (BAS-EGM).

Single interbeat intervals of each EGMs are selected, QRS-waves are blanked, and diastolic intervals are filtered in the 20 - 100 Hz bandwidth for each interbeat interval, then the frequency corresponding to the maximum power spectral density over all the diastolic traces is computed and considered as the characteristic parameter for that file. At least 20 beats for each EGM are investigated.

Results show that unexpected electrical activities have overall median value of 36 Hz (Bas_EGM is 41 Hz, and VT-EGM is 35 Hz). At this stage of the study median values of Bas-EGM and VT-EGM are not significantly different at 5% level (p<0.16 using Mann Whytney U-test for significance of medians).

1. Introduction

Patients at risk of sudden cardiac death can receive implantable cardioverter defibrillators (ICD) as save-life prosthesis. ICD allows continuous monitoring of cardiac electrical activity; they can sense and store intracardiac electrogram (EGM) when a ventricular tachychardia (VT) or fibrillation (VF) occur, as well as during normal cardiac condition at periodical follow ups. Availability of these EGMs, monitored intracardially continuously during time and in different cardiac rhythm condition, opened-up the possibility to get new insight into the heart electrical activity. In particular it could be interesting to examine latent reaction of heart muscle to mechanical stress, potentially coming from thoracic myopotentials or diaphagmatic muscle.

Not many studies have been found in the literature about these topics, nevertheless some analysis focused on case studies have been reported. Such events have been observed and related with inappropriate sensing of previous ICD generations. In particular some studies report that oversensing of pectoral myopotentials and/or diaphagmatic muscle activity determined inappropriate electrical diagnosis and therapy of ICD device [1, 2]; in other investigation the presence of myopotential may have caused inappropriate shock delivery in some patients [3-5], eventually a patient had multiple tachyarrhthmias as a consequence of his simple sleeping on his chest rather then on his back [6].

This paper does not focus on any particular clinical event, rather it focuses on EGM obtained from ICD recipients to determine frequencies of detected myopotentials, even when they are not dominant and the ICD device does not make any misdiagnosis because of them. In this way it is proposed a characterization of such unexpected electrical activities, sometimes observed during the diastolic cardiac intervals and thus not directly connected with the principal heart electrical activity. The characterization is based on power spectral density (PSD) computation.

The investigated questions are: (i) which is the frequency range of these unexpected signals?; (ii) is there any difference between the frequency measured from EGM retrieved immediately before a ventricular tachyarrhythmia initiation vs. those retrieved in basal condition during follow-up?

2. Signals and methods

The present study is based on previously recorded EGMs, thus it is retrospective; it analyzes EGMs retrieved from patients with previous generation St Jude Medical ICDs (model Contour, Angstrom or Profile) between the 1999 and the 2004. Signals were retrieved in a careful manner within the framework of a protocol named ElectA (Electrogram Analysis).

2.1. ElectA data base and protocol

Within this data base about 500 EGM were retrieved from about 70 patients. They included bipolar signal (measured between the proximal and distal electrodes on the electrocatheter) and far-field EGM (measured between the coil and the active ICD device can); different cardiac rhythm have been retrieved: more than 180 EGMs with ventricular tachyarrhythmias, more that 200 recording in basal condition at the follow-up, VF induction and other rhythms.

ElectA protocol required a pre-trigger of at least 20 second that allowed us to analyze basal heart condition immediately preceding the onset of tachyarrhythmias. Moreover, since patients were supposed to go to hospital for periodical follow-up for ICD device testing, during the follow up a supplementary EGM recording was made so that the EGM could be retrieved in basal cardiac condition. ElectA data base includes EGMs sampled at 125 or 250 Hz for a time interval varying between 30 seconds and 4 minutes with 7 bits resolution.

2.2. Intracardiac electrogram signals

For this study a subset of the ElectA database is considered: EGMs obtained from 5 patients are use;. eighteen EGMs are recorded from ICD at time of automatic VT recognition operated by ICD devices (VT-EGM) and 11 EGMs are retrieved in basal condition (Bas-EGM) while the patient is resting at the Hospital during periodic follow-up. The requirement of at least one Bas-EGM and one VT-EGM for each patient is assumed.

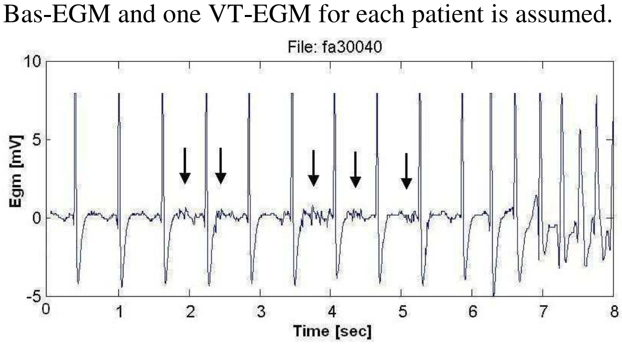

Figure 1: Example of VT-EGM interval with unexpected electrical activity at its baseline during diastolic phase a few seconds before ventricular tachyarrhythmia initiation. Arrows evidence unexpected electrical activities.

The investigated EGM intervals are carefully selected in order to avoid EGM tracing with premature ventricular contraction. Moreover, when a VT-EGM is considered, the EGM is visually inspected by a cardiologist and the timing of VT-onset is recognized, then the 20 sec immediately preceding VT-onset are analyzed; when a Bas-EGM is considered, an EGM time interval of a similar length is analyzed.

Figure 1 shows an example of EGM retrieved with the presence of unexpected electrical activity a few seconds before VT initiation..

2.3. Procedure of signal analysis

Signal analysis procedure include a first pre-processing aimed to eliminate the higher frequency component of the EGM signal, followed by a filtering in the 20-100 Hz bandwidth. It consists of the following steps:

1. Both in Bas-EGM and VT-EGM, R peaks are automatically recognized and blanked by substituting EGM interval including the QRS by a ramp;
2. The portion of the EGM included between blanked QRS waves is considered for this analysis, then each *between-QRS-wave* interval (lasting at least 400 msec) is filtered with a Butterworth 25 – 100 Hz band-pass filter to eliminate the effect of cumulative systolic atrial activity (P wave) and ventricular repolarization activity (T wave). Figure 2 shows the first 10 *between-QRS-wave* filtered EGM for the same signal shown in Fig. 1.

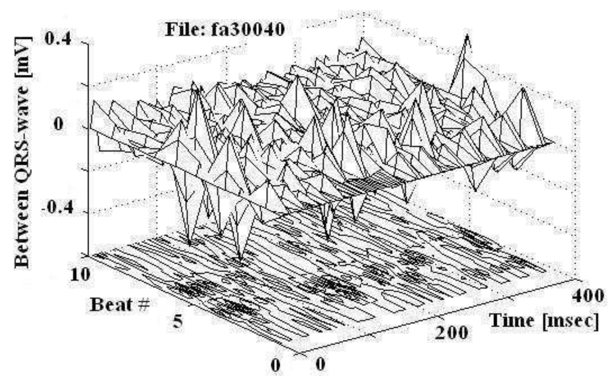

Figure 2: Ten filtered *between-QRS-wave* recording, lasting 400 msec each are shown. A contour plot is drawn beneath the mesh. The EGM is the same presented in Figure 1.

3. Power spectral density (PSD) of each filtered *between-QRS-wave* EGM interval is computed; Hanning window is used before PSD computation. Power spectral density obtained for the same *between-QRS-wave* filtered EGM interval shown in figure 1 and 2 is plotted in Fig. 3.
4. Maximum PSD values along with its corresponding frequency are determined for each inter-beat interval and compared; the maximum PSD is stored and used as a reliability index for that file, while the frequency corresponding to it is considered as the characteristic parameter for that EGM recording.

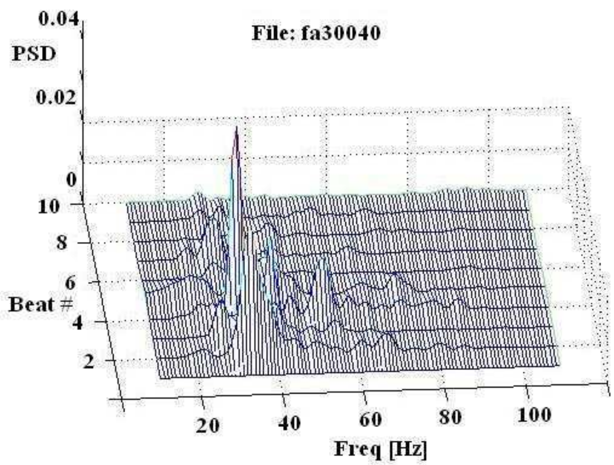

Figure 3: Power spectral densities computed on the 10 EGM traces shown in Figure 2.

2.4. Statistical analysis

For the analysis of the EGMs software included in the Physiotool are used [7]; figures are made using MATLAB software; MATLAB and PAST application [8] are used for statistical analysis, eventually other analysis are done by designing and implementing software in FORTRAN.

Group characteristics are expressed in term of median value, 25th and 75th percentiles. To test significantly different median values between two groups, the non parametric Mann-Whytney U-test is used; difference are considered significant when $p<0.05$.

3. Results and discussion

In this study 29 EGMs obtained from 5 ICD recipients are analyzed. Eleven signals constitutes Bas-EGM group and are retrieved from the patients at the follow-up, while VT-EGM group includes 18 EGMs and are stored immediately before the onset of a ventricular tachyarrhythmia.

The analysis obtained considering all the 29 EGM signals shows that the frequency corresponding to the maximum value of the power spectral density is mostly concentrated between 30 and 45 Hz; a more quantitative description show a median value of 36 Hz with 25th and 75th percentiles of 32 and 44 Hz respectively.

Separate analysis for the two groups lead to values of 41 Hz [34, 45] Hz for Bas_EGM group and 35 Hz [31, 43] Hz for VT_EGM population.

A qualitative inspection of the two groups are shown in Figure 4, where the frequencies of the maximum PSD obtained from each considered EGM signal are plotted vs. the PSD value itself.

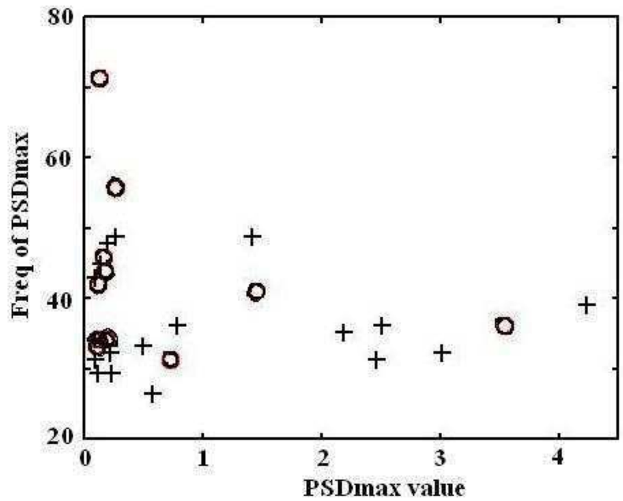

Figure 4: Frequency of the maximum value of PSD vs the measured PSD value for the 29 characterized EGMs.

No separation line has been considered in Figure 4. Indeed small PSDmax values likely means that the measured frequency does not reflect the presence of a reliable unexpected electrical activity. The parameter that has been considered as characterizing index is the frequency corresponding to the PSDmax value, keeping PSDmax value as a reliability index.

A quantitative statistical comparison of the median values of the frequency corresponding to the maximum PSD value in the considered interval of each signal that are obtained show that median values of Bas_EGM and VT_EGM groups are not significantly different at 5% level ($p<0.16$) using Mann-Whytney U-test..

4. Limitation

This work consider 5 patients and 29 EGMs, these are not sufficiently high number to make reliable statistics, thus the first limitation is the small casistic.

A second limitation of this investigation is that no healthy patients could be analyzed because only ICD recipients are considered; moreover patients included in ElectA protocol were receiving an ICD in secondary prevention, thus they had compromised hearts. For this reason we do not have the possibility to compare between compromised and normal cardiac conditions.

A third limitation is that changes in drugs delivered to patients have not been carefully stored, thus we are unable to connect changes in the characterizing parameter with change in the therapy.

5. Conclusion

This paper proposes the investigation of cardiac electrical activity away from the PQRST waves, by examining the heart electrical activity during diastole. It is observed a peak of the power spectra at a median frequency of 36 Hz, while no significant differences between median values obtained from Bas_EGM vs. VT_EGM are observed.

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References

[1] Karanam S, John RM. Inappropriate Sensing of Pectoral Myopotentials by an Implantable Cardioverter Defibrillator System. PACE 2004; 27:688–689.

[2] Babuty D, Fauchier L, Cosnay P. Inappropriate shocks delivered by implantable cardiac defibrillators during oversensing of activity of diaphagmatic muscle. *Heart* 1999;81:94–96.

[3] Deshmukh P, Anderson K. Myopotential Sensing by a Dual Chamber Implantable Cardioverter Defibrillator: Two Case Reports. J Cardiovasc Electrophysiol. 1998;9: 767-772.

[4] Schulte B, Sperzel J, Carlsson J, Dursch M, Erdogan A, Pitschner HF, Neuzner J. Inappropriate Arrhythmia Detection in Implantable Defibrillator Therapy due to Oversensing of Diaphragmatic Myopotentials. Journal of Interventional Cardiac Electrophysiology 2001;5:487–493.

[5] Peters RW, Cooklin M, Brockman R, Shorofsky SR, Gold MR. Inappropriate Shocks from Implanted Cardioverter Defibrillators Caused by Sensing of Diaphragmatic Myopotentials ICD Shocks from Diaphragmatic Myopotentials. Journal of Interventional Cardiac Electrophysiology 1998;2:367–370.

[6] Eckart R, Hruczkowsky TW, Stevenson WG, Epstein LM. Myopotentials Leading to Ventricular FibrillationDetection After Advisory Defibrillator Generator Replacement. PACE 2006; 29:1273–1276.

[7] Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng CK, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* 101(23):e215-e220, 2000.

[8] Hammer O., Harper DAT, Ryan PD. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 2001;4:9

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