

A Matlab program to quantify low-SNR pacemaker signals

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Abstract: In an attempt to study the influence of varying distances between bipolar atrial pacemaker electrodes on ventricular far-field oversensing, we have chosen to analyse signals recorded directly from the patients cardiac pacemaker, via its programmer unit, to a digital acquisition board under several test conditions. This data is analysed by a GUI-driven Matlab program for their near- and far-field parameters spike amplitude and width, frequency of occurrence, and average potential shape. Far-field events are displayed together with their preceding near-field over the whole recording period by a raster-plot display. Our Matlab routines were tested on several patients with a DDDR type pacemaker, but an extensive study under controlled conditions is pending.

Keywords: Atrial pacemaker leads, far-field ventricular signal, programmer unit, Matlab, signal-to-noise-ratio SNR

Introduction

Electrical recordings from atrial pacemaker electrodes are, besides others, composed of atrial activation, ventricular far-fields signals, and electromagnetic interferences [2]. Conventional pacemaking aims to detect the atrial activation, i.e. depolarization signal and tries to reject all signals not of this origin, especially the so called far-field signals resulting from a time delayed recording of the ventricular signal. The current method of choice to accomplish this task is to blank out the signal in a certain, refractory time window. However, this means that part of the sensing capabilities of the pacemaker are ignored on purpose and thus may lead to a reduced ability to detect tachyarrhythmic events. One hypothesis

to suppress or at least to reduce those far-field signals is to utilize bipolar pacemaker leads with a reduced distance from each other to electrically blank out those unwanted signals.

The following reports on a novel, GUI-driven analysis tool to quantify far-field events over the whole time span of an intratrial ECG-recording, while keeping an eye on each single depolarization event.

Materials and Methods

Subjects of a preliminary test group, all equipped with a DDDR-type pacemaker (DR 353, Medtronic Inc., Minneapolis) were asked to perform a simple ergometric walking exercise, while the sensing head of the programmer unit (Type 9790, Medtronic Inc., Minneapolis) was held in place to record from the pacemaker. The pacemaker was prior to exercise set to a DDI 30 value, thus not stimulating and only recording from the patients atrium. Pacemaker leads implanted were CapsureFix 5068 and 6940 respectively.

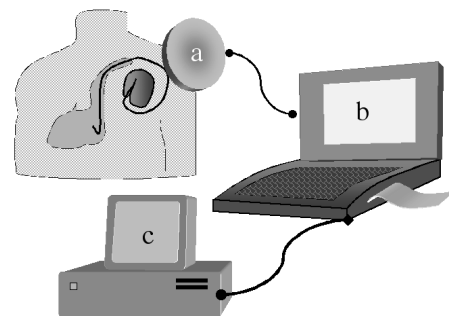


Figure 1: Sketch of experimental setup to use the pacemaker as sensing device.

The implanted pacemaker transmits its recording values inductively to the programmers sensing heads (Figure 1 a) with maximal 8bit resolution and 256 samples/sec. The programmer unit itself (Figure 1 b) offers analogue

output ($\pm 1V$), which we in turn digitise with a simple A/D converter card (Figure 1 c) run under Labview (1kHz sampling rate, National Instrument Corp., Austin, TX, USA). In principle, a re-digitisation of the programmer-unit's data is possible with any type of AD converter card, like e.g. the sound card of a PC (mind the lower cut-off frequency!). This way, the incoming data may be stored as .wav file, whereas our AD cards converts into rows of ASCII text.

Our Matlab-program (The Mathworks, Inc., Natick, MA, USA) reads either ASCII or .wav-data and displays them in the first step. A Matlab "find"-function with the rms-level as threshold marks interesting events [1, 3], which are either atrial depolarizations or ventricular far-field events. In order to interactively assign them to an appropriate group, a histogram plot gives the time between detected "find"-events ("gaps") and allows adjustment of gap borders for further analysis. Four types of gaps occur: Gaps by a zero-crossing event within one depolarisation (Figure 2 a; which are later smoothed out), gaps between a near- and a far-field (Figure 2 b), gaps between a far-field and a subsequent near-field (Figure 2 c), and gaps between subsequent near-fields (Figure 2 d).

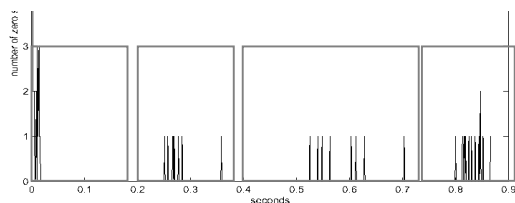


Figure 2: Histogram of times (in sec) between subsequent events, used to assign the appropriate events to the far- and near-field category.

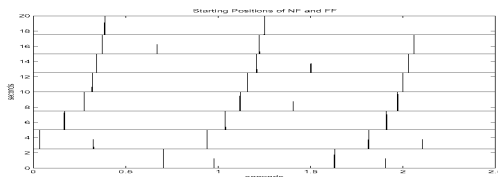


Figure 3: Raster plot: Display of onset times of either depolarisation events (full sized vertical line) or far-field events (half sized vertical lines) over a portion of a full ECG-record.

This categorisation is then used to store, display and analyse appropriate event data. We display time courses of near-field and far-field amplitude and width. The latter is used in place of the poorly detectable rise-time of the depolarisation spike.

Deducted from this are ratios in amplitude and width of

appearance of far-fields. The complete file may be displayed in a raster-plot, displaying only categorised events (Figure 3).

We finally produce a so called "spike template" by displaying an average of all detected depolarisation events with the according error (Figure 4). The average is either aligned to its maximal amplitude or its first zero crossing, depending on which method minimises the variance.

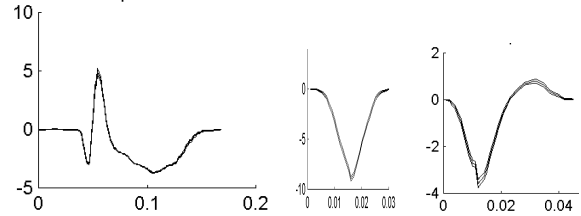


Figure 4: Examples of depolarisation templates of 3 different patients. Note the differences in scale.

Results and Discussion

We developed a simple Matlab-program to analyse the low-SNR ($\approx 6:1$) signals from intra-atrial pacemaker electrodes. This program can be downloaded under www.isip.mu-luebeck.de/~hofmann/Paper/ECG/.

Table 1 shows example results of one patient, shortly after the implantation of his pacemaker.

Table 1: Example results of one subject's ergometric exercise

File	Sampling period (sec)	Amp NF	Width NF / msec	NF/FF Amp	FF in %
Prae	20-120	3.9	21.3	1.9	46.23
post	0-105	4.5	20.8	2.2	62.18
ergo1	0-95	4.2	21.0	2.0	10.71
ergo2	0-95	4.1	26.1	2.0	25.6
ergo3	0-100	4.1	27.3	2.0	15.33
ergo4	0-95	3.9	24.6	1.9	13.99

A thorough medical investigation with a bigger subject pool is pending and will be published elsewhere, but the use of our intuitive program enables us to quantify all recorded low-SNR signals with high reliability and precision.

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