ECG DATA IN IDENTITY CARD FORMAT

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Summary: *ECG data inscribed in identity card format may be very useful once for comparison between the heart state before and after eventual accident and secondly for holding the recording of previous heart disturbances. We elaborate software, which gives doctors the opportunity to print in appropriate format a selected 12 leads P-QRS-T interval for express morphological analysis and a relatively longer record of the II lead for rhythm analyses.*

Introduction

A lot of accidents with people happen at the street, in public transport, on vacation, abroad etc. It is very useful and time-saving for the urgency ambulance team to have on their disposal the blood group and the electrocardiogram (ECG) of the sufferer for comparison between the heart state before and after the accident and for previous heart disturbances information. It is not far in the future that such information will be stored either in the Identity (ID) Card or in specially designed Medical Insurance card magnetic holders. Nowadays the ECG data can be recorded at least on a sheet of paper with the same as the standard ID card size. It can be laminated afterwards and easily deposited and carried around together with the ID.

The purpose of our work is to extract, choose and record condensed ECG data at the same format as the ID. For compactness the record sheet should contain a selected 12 leads P-QRS-T interval and a relatively longer II lead of the patient's electrocardiogram for morphological and rhythm analysis, respectively.

There are two possibilities when making decision which P-QRS-T interval is convenient to be used for inscribing ECG data in ID format. The first gives the doctor the opportunity to mark it manually, and the second one applies an algorithm for automatic choice.

Method and algorithm

The program for ECG data inscribing in ID card format is written in Visual Basic environment. The QRS complexes are detected using the Caceres' algorithm [1,2]. The onset and offset of each QRS is determined searching for low slew rates intervals left and right from the detected QRS fiducial point. The area (signal integral) is calculated for each QRS complex. These integrals are sorted and the second in rank small integral is picked up and is used for ECG data inscribing in ID format. Thus we avoid the possibility ventricular extrasystoles, having as a rule bigger signal integral then this of the normal beats to be taken into consideration. On the other hand the choice of the 'second in rank small signal integral' protects the method against false QRS detections caused by huge electromyographic noise, electrode disconnections, etc.

QRS complexes detection using the Caceres' algorithm

The Caceres' algorithm consists of the following steps.

First the signal must be processed by a 50Hz band-stop filter for elimination of the power-line interference and by a first order high-pass filter with 3.2s time constant τ for suppression of the base-line wander. The chose of the τ value is strongly recommended for the subsequent morphological analysis [3-5].

Then the first derivative of the ECG signal is calculated using samples, 10ms apart. The obtained signal is divided in equal intervals of 370ms length. The minimum value of the derivative – *Dmin* is detected for each of the intervals. Next the minimum value of all *Dmin*, called *M*, is found. A signed threshold equal to *5/8* of *M* is set and all *Dmin*, which are above it are cancelled. If the interval between two consecutive *Dmin* is shorter than 184ms it is considered that they belong to one and the same QRS complex and the bigger one (smaller in absolute value) is cancelled.

We used the minimum value for the derivative (*Dmin*) because the RS segment of the QRS complex is considered to be the steeper one.

QRS Onset and Offset determination

The Onset (or Offset) of the QRS is determined searching for 10 ms 'flat' intervals with low slew rate changes of the signal on the left (or right) from the detected QRS fiducial point. For a sampling rate of 1000 Hz, the 'low slew rate criteria' is fulfilled if:

1. Any one of 10 differences between adjacent signal samples is smaller then a Predefined Value.

   For QRS Onset: *Sample(i) – Sample(i–1) < Predefined Value*
   For Offset: *Sample(i) – Sample(i+1) < Predefined Value*

2. The difference between the first and the tenth sample in the interval is smaller than the same *Predefined Value.*

   For QRS Onset: *Sample(i) – Sample(i–10) < Predefined Value*
   For QRS Offset: *Sample(i) – Sample(i+10) < Predefined Value*

The first sample at the beginning of the slew rate interval is marked as the Onset (or the Offset) of the detected QRS complex.

Selection of representative QRS

The sum of the absolute signal values between the Onset and the Offset of each detected QRS complex is computed.

$$Sum(j) = \sum_{i=Onset(j)}^{Offset(j)} SignalSample(j)(i)$$

where j is the number of the QRS complex and i is the QRS's inner samples

The $Sum(j)$ are sorted in increasing rank. Pundjev [6] in his Ph.D thesis selects the Sum having the smallest integral. Thus he eliminates the ectopic beats that normally have large width relating to a higher integral. Our experience working on more then 400 patient's database showed that high-frequency single artifacts caused by huge electromyographic noise, electrode disconnections, etc. often produce a false QRS detection. For that reason the complex, which corresponds to the sum at the second position from the bottom, is assumed to be most relevant and representative for inscribing in identity card format.

ECG Spatial vector

Daskalov et al. [7] suggest that the P-QRS-T complex time-parameters should be searched for in a compound lead for example, the ECG spatial vector magnitude V_{SP}. An approximate procedure for obtaining V_{SP} involves three quasi-orthogonal leads **X, Y** and **Z,** where

$$X = 0.5[(C_4 - Z_0) - [(C_1 - Z_0)],$$
$$Y = -(R - Z_0),$$
$$Z = [(R - Z_0) - (C_2 - Zo)]$$

R, C1, C_2 and C_4 are the primary leads having signal acquisition with respect to the left leg F [8] and Z_0 is the Onset of the selected QRS. Then:

$$V_{SP}=0.5[(|X|+|Y|+|Z|) +0.25(||X|-|Y|| + ||X|-|Z|| + ||Y|-|Z||)]$$

The Spatial Vector is further filtered with cubic approximation working in 15 ms approximation interval [9].

P wave onset and T wave Offset determination

The P wave Onset and T wave Offset are searched for in time-interval windows depending on the R-R interval [8]. The search is completed on the Spatial Vector V_{SP}. The peaks of both waves are detected first and then sliding to the left (for the P wave), respectively to the right (for the T wave) the P Onset and the T Offset is determined by the same 'flat' segment searching algorithm, discussed above.

The doctor has the opportunity either to acknowledge the P-QRS-T selection or to search and mark another more convenient interval.

ID format signal recording

The 12-lead electrocardiogram is obtained by the 8 primary leads, using the formulas in Dotsinsky at al. [8].

The ID format recordings is made in 3-leads series - I,II,III - aVR,aVL,aVF - V1,V2,V3 - V4,V5,V6. In addition 5.6s of lead II is registered at the bottom. Very often the leads overlap, especially in the higher amplitude chest leads. The first and the second lead's triples are of lower amplitudes. That's the reason to print there the patient data (Name, ID No, etc.).

The centering of the leads is made separately for any of the triples and includes the following steps:

- Determination of the peak-to-peak amplitude A_{PP} for any of the lead in the corresponding triple. A_{PP} determination of lead II in the first 2.8 s for triples - I,II,III - aVR,aVL,aVF and in the last 2.8 s for triples - V1,V2,V3 - V4,V5,V6.
- Summing the four amplitudes $A = \sum_{i=1}^{4} A_{PP}(i)$.
- Let D is the height of the ID card format. The difference $B=D-A_{PP}$ is formed.
- In cases of low amplitude leads $B>0$ and there is no overlapping (Fig. 1a). An interval $I=B/4$ is formed between the channels and the lead's centering is:

$$Ch1(j)=Ch1(j)-min1+I/2$$
$$Ch2(j)=Ch2(j)-min2+App1+1.5*I$$
$$Ch3(j)=Ch3(j)-min3+App1+App2+2.5*I$$
$$Ch4(j)=Ch4(j)-min4+App1+App2+App3+3.5*I$$

- In high amplitude cases ($B\leq 0$) where the leads overlap no interval at the paper top and bottom are provided, i.e. $I=B/3$. The centering of the channels is shown in Fig. 1b. In overlapping I is negative.

$$Ch1(j)=Ch1(j)-min1$$
$$Ch2(j)=Ch2(j)-min2+App1+I$$
$$Ch3(j)=Ch3(j)-min3+App1+App2+2*I$$
$$Ch4(j)=Ch4(j)-min4+App1+App2+App3+3*I$$

Here j is between 1 and the number of signal samples.

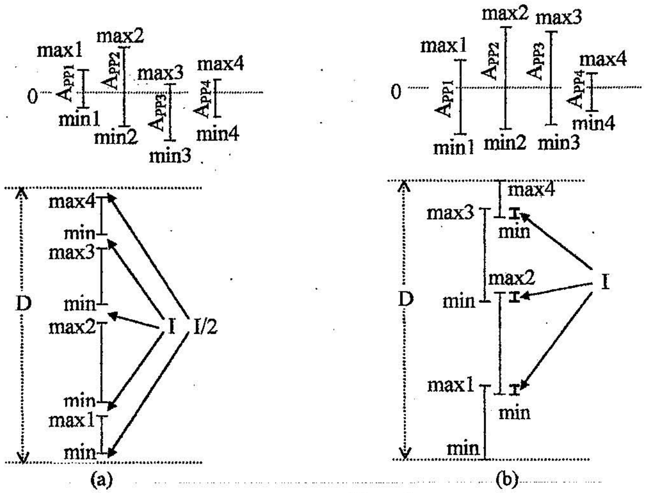

Figure 1

Low amplitude ECG inscribed in ID format is shown in Fig. 2
High amplitude ECG inscribed in ID format is shown in Fig. 3

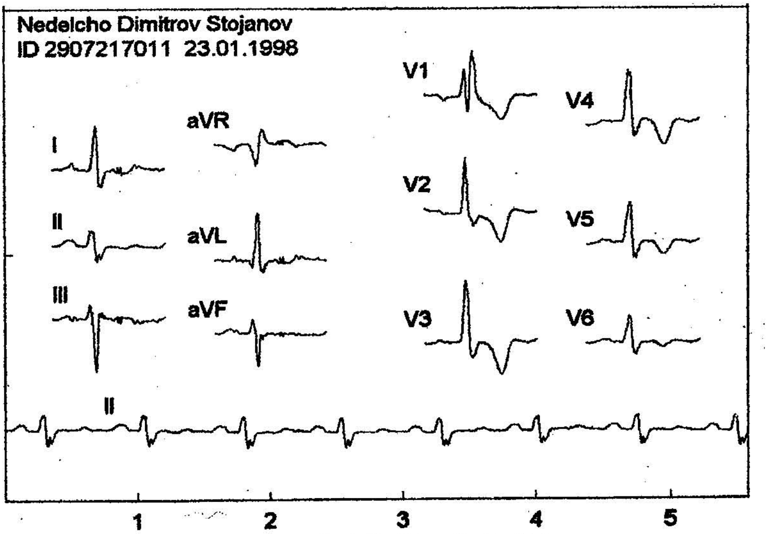

Figure 2. Low amplitude ECG inscribed in ID format

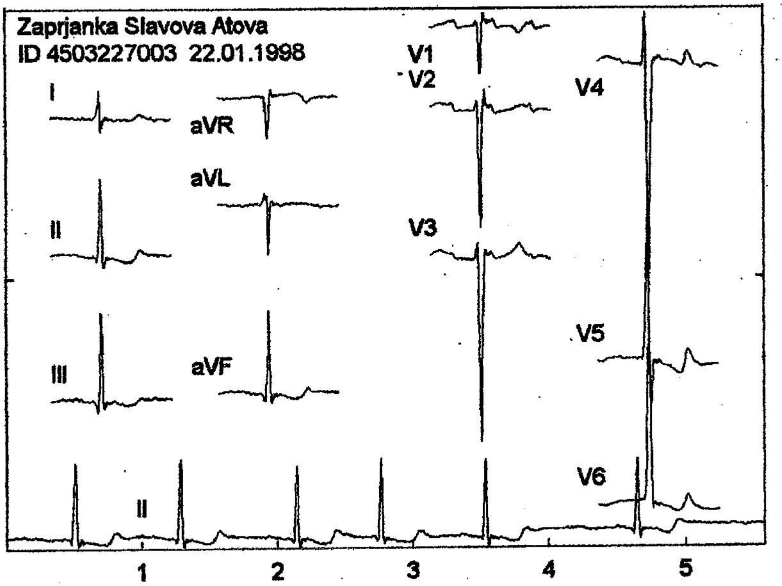

Figure 2. High amplitude ECG inscribed in ID format

Conclusion

ECG data inscribed in identity card format contains patient's ECG data, which is enough for express morphological and rhythm analysis. This is very convenient when suddenly occurring unfortunate circumstances impose an unfamiliar physician to take care for the patient.

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