Extension of the HES Program for Processing Pediatric ECGs

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Abstract

Computer assisted analysis of pediatric ECGs is still somewhat weak. Problems arise from signal processing. QRS complexes from newborns are very short and show steep amplitude. Very high heart rates with narrow intervals between T and P waves introduce difficulties for the wave recognition algorithms. For diagnosis problems arise due to rapid changes of characteristic ECG parameters with age. Reference data for normals have been published by several authors but differ in part markedly. For the HES ECG analysis program a new module has been introduced which presents selectable characteristic ECG parameters and associated normal limit ranges for the physician's decision making.

1. Introduction

Computer-assisted analysis of pediatric ECGs is still not widely used. There are problems in signal processing (high heart rates, small and steep QRS complexes and often high noise). Due to rapid changes of characteristic ECG parameters with age development of interpretative algorithms requires many age stratified data subsets for Normals and respective disease groups.

Furthermore quite a majority of congenital heart diseases are detected and validated by echocardiography. ECG analysis is more focussed on arrhythmia symptoms, prolonged QT etc.

First publications on computer programs for analysis of pediatric vectorcardiograms appeared 1977 by Zywietz et al. [1] and 1983 Brohet et al. [2].

On development of programs for pediatric 12 lead ECGs reports have been published 1979 by Hamilton et al. [3], 1981 by Francis et al. [4], 1986 by Laks et al. [5], 1990 by Macfarlane et al. [6] and 2001 by Rijnbeek et al. [7].

In this paper we describe the extension of the HES EKG program for evaluation of pediatric 12 lead ECGs. Based on experience with acceptance of automatic classification we provide the HES measurements and the publicly accepted Normal values for the users' own decision making.

2. Methods

2.1. The pediatric VCG program

Our first program for analysis of pediatric vectorcardiograms [1] was based on a set of 729 carefully selected Normals, 204 RVH, 30 LVH, and 160 BVH echo and Cath Lab validated cases. Four subgroups with ages 0-6 month, 7-24 month, 3-6 years and 7-16 years were built and a specific multivariate statistical approach (Multivariate Alternativ Klassification – MAK II) has been utilised for diagnostic classification.

Because of the large set of Normals a specificity of 98.6% and an overall accuracy of 85.9% could be reached.

2.2. The pediatric 12 lead ECG program

Unfortunately only a small percentage of cardiologists use the VCG regularly in clinical practice.

Furthermore, the acceptance is low for pure statistical interpretative algorithms. The physicians want to verify the reasoning on the basis of morphological features like amplitudes, intervals, amplitude ratios etc.

We have therefore decided to base our pediatric 12 lead ECG analysis program on publicly accepted NORMAL ECG measurement values.

As the pediatric ECGs change significantly with age valid knowledge on ECG parameters and their range particularly of the normal measurements is of paramount importance.

To the authors knowledge the most comprehensive carefully prepared set of normal ECG data has been published by Davignon et al. in 1979/80 [7]. Computer-assisted measurement with expert quality control has been used to asses the normal limits for 12 age groups between 0-24 hours up to 12-16 years. Mean and median values and – among others – the 5%-95% and the 2%-98% limits for each age group are provided. Sample sizes of 109-247 cases per age group provide reasonable confidence even into the borderline values.

In publications by Macfarlane [8] and Rijnbeek [9] some different results on normal limits have been presented claiming specifically some higher amplitude

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values and excessive larger 98% normal limits due to higher sampling rates in their own data recordings. Also, the QRS durations where claimed to be larger than given in the Davignon publication. Rijnbeek presents Medians and 2%/98% for females and males. Only for the age groups 6-12 month and above 5 years more than 100 ECGs were measured, i.e., only for those groups 2% and 98% limits will be reasonably reliable.

Already Davignon et al. mentioned that the computer measurement of the globally (over 12 simultaneous leads) determined QRS duration (QRS_D) was ca. 5 ms longer than the V5 QRS_D. To verify the difference between QRS_D of lead V5 and the global QRS_D for the 12 simultaneous leads we have measured a set of 254 normal ECGs from our database. Additionally we have looked at measurements of QRS_D from 605 Normals obtained by Masač [10]. The results are shown in figure 1.

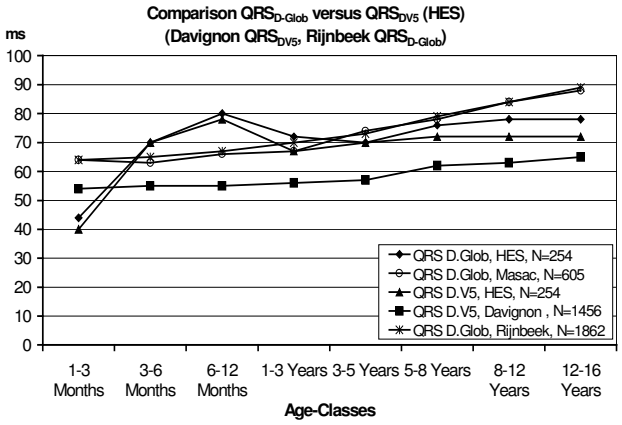

Figure 1. Median Normal QRS_D by different authors.

As predicted by Davignon the QRS_D in V5 has been found also by the HES program ca. 7 ms shorter than the global QRS_D. (Since the 254 cases study did contain only few cases in the lower age groups only groups with age > 5 years did show significant differences).

Both Masač and Rijnbeek find almost identical (global) QRS durations for the age groups > 1-3 months and these medians are 10-23 ms larger than the values by Davignon. Since today almost all computer programs measure intervals from simultaneously recorded leads the somewhat larger QRS duration normal limits deserve serious consideration.

The situation is different for RV6 amplitude measurements. As depicted in fig. 2 the RV6 median amplitudes measured by Davignon, Masač and HES resemble well while the measurements of Rijnbeek are larger by 25-30%. For the lowest age group, however, Davignons' medians are above the Masač measurements.

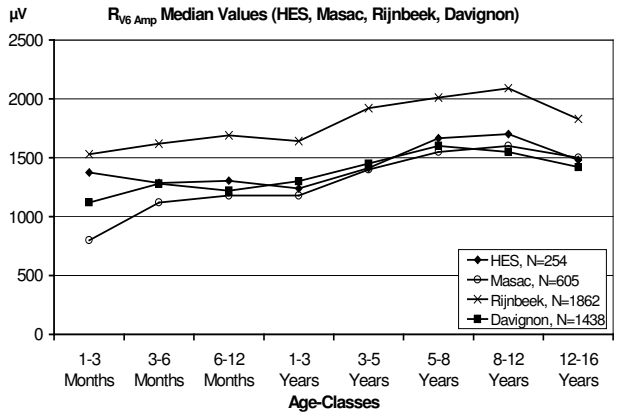

Figure 2. Median normal RV6-amplitudes by different authors.

In view of the RV6 measurement differences the comparison of SV2 amplitude Normal medians as depicted in fig. 4 is strange. In contrast to the RV6 measurements the Rijnbeek and Davignon medians resemble very well while the Masač measurements (note these data are sampled with 500S/s as the Macfarlane data) are somewhat lower and the Macfarlane data show not very plausible differences between the three lower age groups.

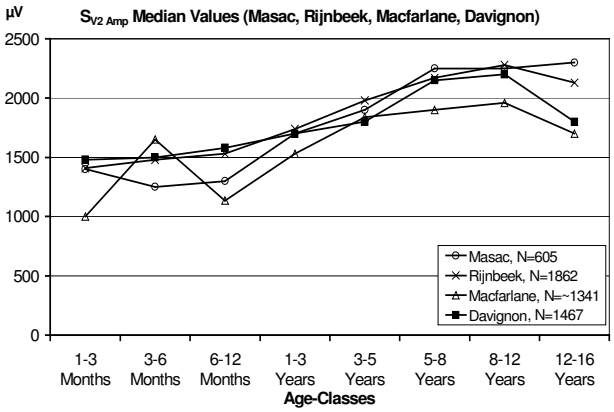

Figure 3. Median normal SV2-amplitudes by different authors.

These differences in the Normal references can not be explained just by different sampling rates. They require careful further consideration and possibly new data bases.

3. Results

Because of the different published normal limits we have prepared a set of different normal limit reference tables according to their authors. Figures 4 and 5 depict the basic program structure and a printout example.

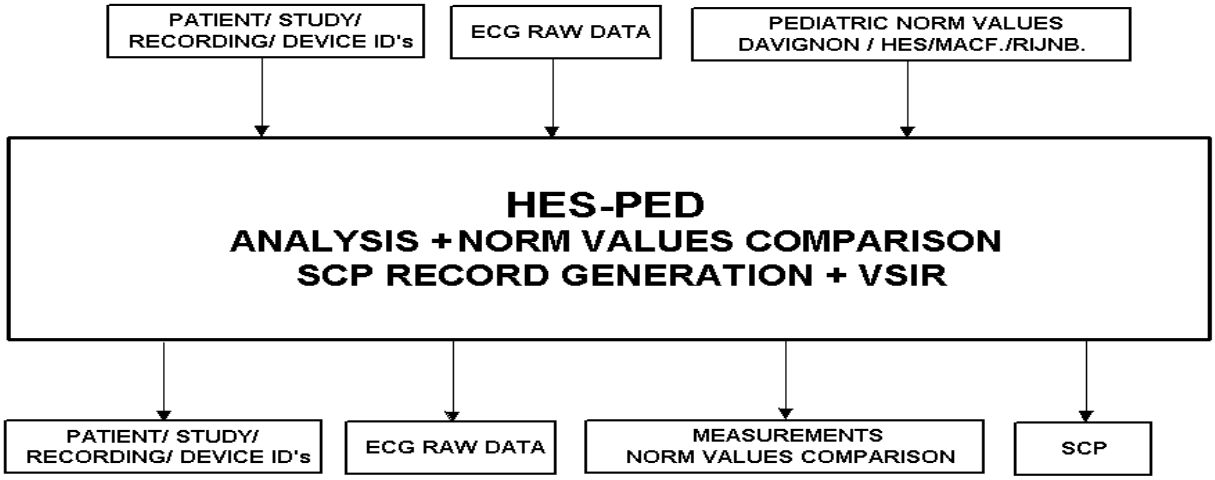

Figure 4. The figure illustrates schematically the derivation of measurements and their combination with normal limit values. Patient and record Id, ECG raw data and tables with pediatric norm values are read in, the ECG is processed by the HES analysis program and selected, characteristic measurements are print out together with the normal value ranges – see figure below.

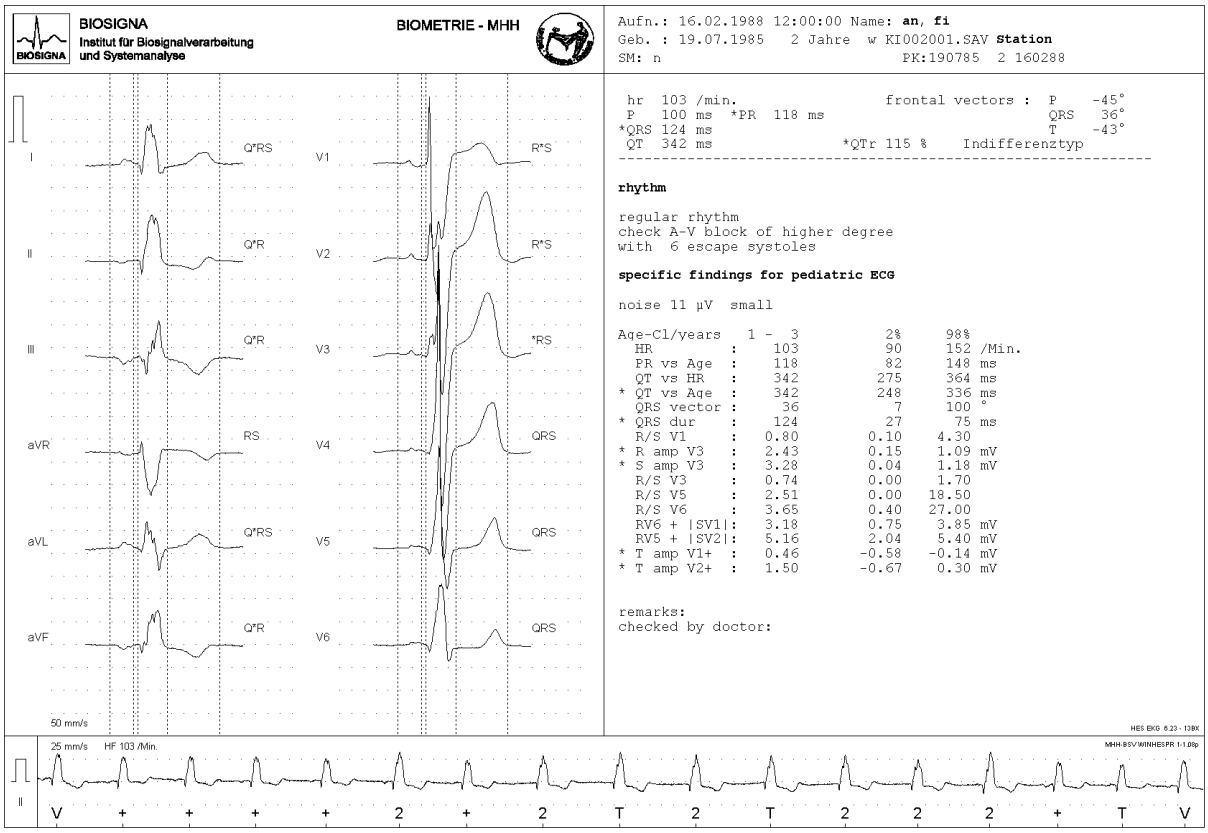

Figure 5. Example for a pediatric ECG analysis report. On the bottom a rhythm strip of a selectable lead with beat annotation is shown. On the upper left hand side the "Representative Cycle" (average beat) with markers for the wave onsets and offsets and for each lead the wave annotation is given. On the upper right side below the age class typically requested wave measurements and their normal ranges are printed. In this case the QT versus age is prolonged, QRS_D is prolonged and R, S in V3 and T in V1 and in V2 exceed the normal range.

4. Discussion and conclusions

In view of the very careful acquisition, analysis and the comprehensive presentation of all data we consider essentially the results from Davignon et al. as the most useful reference normal limits except for the QRS duration. There we use our own normal value limits, which are 10-20 ms higher than the Davignon durations.

As far as the amplitude ranges are concerned we use essentially the Davignon data. Fig. 6 shows as an example the RV6 tolerance ranges published by Davignon and Rijnbeek.

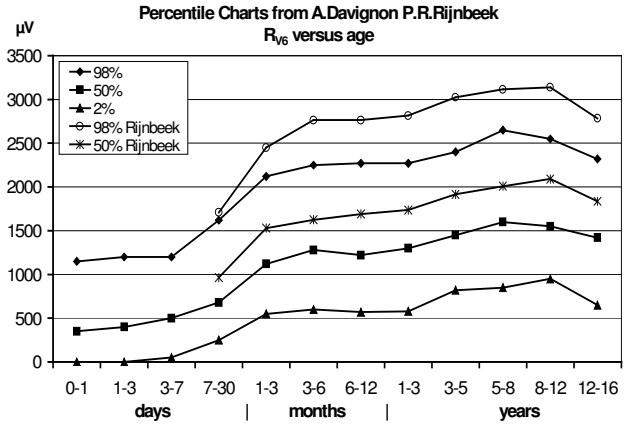

Figure 6. RV6 Medians and 2%-98% ranges by Davignon and Rijnbeek. As can be seen on the diagram the 98% limit of Rijnbeek exceeds the Davignon value by ca. 500 µV for age groups above 3 months!

We doubt that the differences are caused by the different sampling rate, since the S wave measurements do not differ very much.

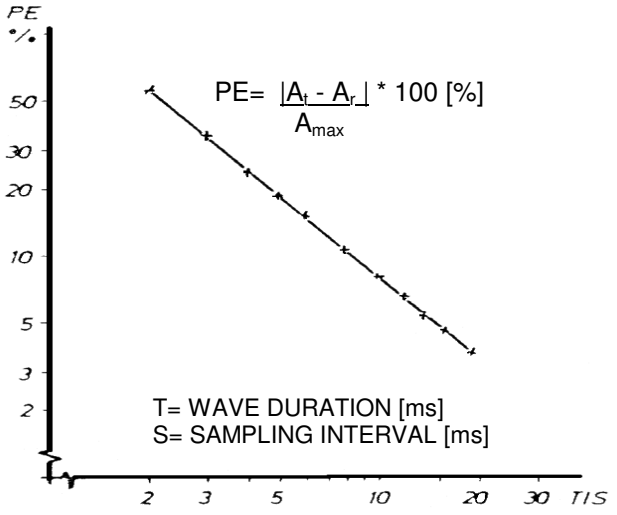

Figure 7. The figure depicts the possible peak amplitude related error dependent on the ratio T/S.

The sampling interval of Davignon data was 3.33 ms. A search in our own pediatric ECG database (on 253 ECGs) has yielded an average R duration of 34.6 ms. The ratio of wave duration/sample interval (T/S) is 34.7/3.33 ~10 which might result in an error of the peak amplitude measurement < 10% [11].

At this point of our knowledge we can only speculate whether ethnic differences or anthropometric differences could explain as well the deviating measurement results. As a consequence it must be concluded again that we need to establish further, hopefully shareable, data bases.

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