Comparative Analysis of the Parameters Affecting AED Specificity: Pediatric vs. Adult Patients

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Abstract

A pediatric and an adult database, with 550 and 443 samples respectively, are used to test the efficiency of the AED analysis algorithm originally developed for adult rhythms. Statistical analysis of the four significant parameters that define the shock-noshock classification algorithm has been performed. Following parameters are considered: Pulse Rate (PR), Waveform Power Ratio (WPR), and two morphological parameters, Baseline Content (BC) and Probability Distribution Width (PDW).

The specificity of the classification algorithm is measured and compared to the AHA goals. The result for pediatric Sinus Normal rhythms is 100% specificity, and 78.95% for other nonshockable rhythms. The likelihood of an AED to inappropriately shock pediatric rhythms is thus analyzed.

1. Introduction

In 2003 the International Liaison Committee on Resuscitation (ILCOR) updates and clarifies the previous recommendations about the potential use of Automated External Defibrillators (AED) in children. This update has become critical due to the growth of numbers of AEDs for adults being placed in public access settings, the increase of the use of AEDs by non traditional responders, and the likelihood for using it with patients younger than 8 years of age.

The ILCOR recommendation [1] expands the use of AEDs with children 1 to 8 years of age who have no signs of circulation. There is insufficient evidence to support a recommendation for or against the use with children <1 year of age.

Several considerations are to be taken to determine whether the AEDs designed for use in the adult are effective and safe for children. Firstly, the delivered energy has to be adapted to children, who require a much lower defibrillation dose. This can be obtained using pediatric pad/cable systems that reduce the delivered energy. Secondly, the rhythm analysis must be evaluated to determine its capability to safely differentiate between shockable and nonshockable rhythms in children.

The rhythm analysis program of one AED system generally satisfies the sensitivity and specificity criteria recommended by AHA for the performance of an AED [2]. But having been developed and tested with adult databases, the algorithm should be assessed using pediatric arrhythmia databases in order to demonstrate its efficacy in this patient population.

Two studies have been recently published dealing with that issue [3, 4]. Both of them show that the AED algorithms developed for detecting adult arrhythmias can provide highly specific and reasonably sensitive rhythm analysis in infants and children.

In this paper the algorithm of a commercial AED has been evaluated using a pediatric database obtained from two Spanish hospitals. It has been tested with pediatric non-shockable rhythms in order to analyze the specificity. The parameters used by the decision algorithm have been computed and compared to those obtained with an adult database available from previous studies. The results will show the likelihood of an AED to inappropriately shock pediatric rhythms.

2. Materials and methods

Two databases have been used in this study. The adult one consists of records extracted from commercial databases (AHA and MIT databases), and Spanish hospital and emergency services. The pediatric database has been completely obtained using exclusively Spanish hospitals.

The adult database fulfills the requirements set by the AHA recommendation [2] to report the performance of an AED algorithm, and it has been used for the developmental testing of the algorithm implemented in the AED Reanibex 200, currently being commercialized by Osatu S. Coop. (Ermua, Spain). It consists of samples with a mean duration of 15 s, corresponding to a unique rhythm each, with no artifacts, and only one record per patient and type of rhythm has been considered. A summary of the complete database is shown in Table 1.

The pediatric rhythm database was created from archived ECG studies of patients under 14 years of age. They were collected in Cruces Hospital in Barakaldo and La Paz Hospital in Madrid during the last two years. The rhythm collection criteria are similar to those applied for the adult database, but more than one record per patient and type of rhythm has been permitted. A summary of the complete database is shown in Table 1, and detailed description is available in [5]. The database does not conform to the number of samples per rhythm required in [2], but specificity can be analyzed.

Table 1. Distribution of the rhythms in each database.

	Adult	Pediatric (0-14)	Pediatric (1<&<8)
NSR	187	359	278
Others:	256	191	85
BII	13	16	10
IVR	11	0	0
AF	31	2	1
SB	23	12	7
TSV	67	145	56
PVC	111	16	11
Total no-shock	**443**	**550**	**363**
VT	74	59	22
VF	200	53	12
Total shock	**274**	**112**	**34**

In this study only the nonshockable rhythms have been considered to measure specificity. A total of 443 adult and 550 pediatric records have been used, divided into the following rhythms: NSR (Normal Sinus Rhythm), IVR (Idioventricular), BII (Heart Block), SB (Sinus Bradycardia), PVC (Premature Ventricular Contractions), AF (Atrial Fibrillation, Atrial Flutter), SVT (SupraVentricular Tachycardia, including Bundle Branch block, Sinus Tachycardia and Atrial Tachycardia), VF (Ventricular Fibrillation) and VT (Ventricular Tachycardia).

The group of Asystole has not been considered as no pediatric records are available yet, and because we consider that the detection of asystole based on the amplitude and energy level of the ECG will be pretty similar for adult and patient asystole episodes.

The analysis algorithm tested is a Matlab PC version of the detection algorithm of the AED Reanibex 200, which is detailed in [6]. It consist of a decision tree build on the values of 4 significant parameters, which are computed for every 4.8s length window, and compared to empirically set thresholds to decide if the analyzed ECG is shockable or not. This algorithm satisfies the sensitivity and specificity criteria of the AHA recommendation [2].

The four parameters used in the decision algorithm measure different characteristics of the rhythm samples. The first parameter considered is the Pulse Rate (PR), which corresponds to the rate of the ECG complex occurrence in NSR rhythms and with the waveform dominant frequency in general. It is computed using the autocorrelation of the signal, and given in beats per minute (bpm). The higher the PR value, the higher the probability of being a shockable rhythm.

The second parameter, the Waveform Power Ratio (WPR) measures the percentage of the power that the ECG signal concentrates around the PR. It is computed in the frequency domain as the percentage of the power which is in a bandwidth of 90% of the PR around PR. The higher the WPR, the higher the probability of being a shockable rhythm.

The third and fourth parameters are linked to the distribution that the amplitude samples of the ECG waveform show. In nonshockable rhythms most of the samples of the signal are close to the baseline, while in shockable rhythms as VT and VF, the samples show higher dispersion. From the estimated probability density function, the Baseline Content (BC) and the Probability Distribution Width (PDW) are computed. BC is the percentage of the samples concentrated in a band around the baseline. The lower the BC, the higher the probability of being a shockable rhythm. The PDW is the range of amplitude values, in which the 50% of the samples accumulate. The higher the PDW, the higher the probability of being a shockable rhythm.

3. Results

The specificity of the AED analysis algorithm for adult and pediatric databases has been computed Three population have been considered: the adult database (n=443, n indicates the number of samples), the pediatric (including all the pediatric rhythms from 0 to 14 years of age, n=550), and the pediatric group that only considers the children >1 year and <8 years of age (n=363). Specificity results are summarized in Table 2.

Specificity of 100% has been measured in all three databases for Normal Sinus Rhythm, considering n=187 for the adult, n=359 for the pediatric, and n=278 for the pediatric subgroup (>1 and <8 years).

For the other nonshockable rhythms the performance highly differs between adult and pediatric. In the adult database, n=256, only 1 rhythm, corresponding to an Atrial Fibrillation was wrongly classified as shockable, which means a 99.77% specificity.

Table 2. Specificity performance for each database. (n indicates the number of samples)

	NSR	Others
Adult (n=443)	100% (n=187)	99.77% (n=256)
Pediatric (0-14) (n=550)	100% (n=359)	78.95% (n=191)
Pediatric (1<&<8) (n=363)	100% (n=278)	69.73% (n=85)
AHA Goal	**>99% (n>100)**	**>95% (n>30)**

For the pediatric whole database (n=191), 41 samples were wrongly classified, which means a 78.95% specificity. Most of these rhythms, 40, were in the SVT group. In the pediatric subgroup (>1 and <8 years), n=85, 23 rhythms were wrongly classified, providing a 69.73% specificity. Most of which, 22 out of 23, were in the SVT group.

The statistical analysis of the rhythm characteristics shows significant differences in the four parameters for the adult and for the pediatric group. Figure 1 demonstrates the rhythm characteristics as determined by the algorithm.

The adult Pulse Rate is significantly higher (p<0.0001) for pediatric subjects, with a mean rate of 127±52 bpm (mean±std), than for the adult rhythms with a mean rate of 92±44 bmp.

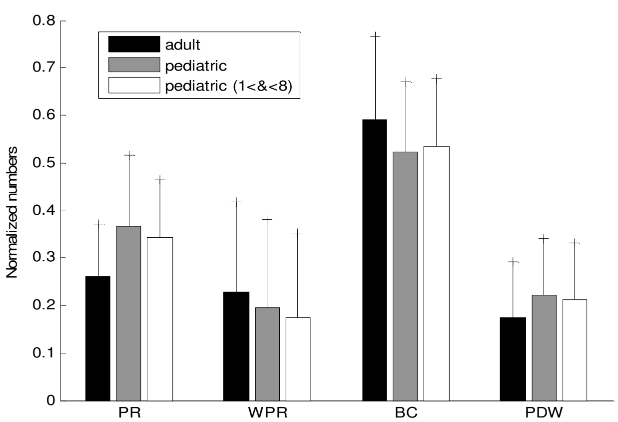

Figure 1. Comparison of the nonshockable rhythm characteristic parameters.

The WPR and the morphology parameters (BC and PDW) obtained for the adult samples differ significantly from pediatric values. The adult mean values for WPR (20±17), BC (57.6±17) and PDW (1.01±0.66), measured in the corresponding units, differ (p<0.0001) from the pediatric values, WPR (18±17), BC (51±14) and PDW (1.28±0.69). These significant differences do not occur between the pediatric complete database and the pediatric subgroup, for which PR (119±72), WPR (16±16), BC (52±13) and PDW (1.23±0.67) have been measured.

The Pulse Rate distribution for the adult database is compared in Figure 2 to the pediatric one. The probability density function has been estimated for the 2 databases of different size and the results plotted. The higher values for the pediatric database with mean of 127±52 bpm are evident. That difference is stronger for the SVT rhythms, with a mean of 123±24 for adult SVT, and 201±34 bpm for pediatric SVT, samples which are discernible around 200 bpm in the distribution of the Figure 2.

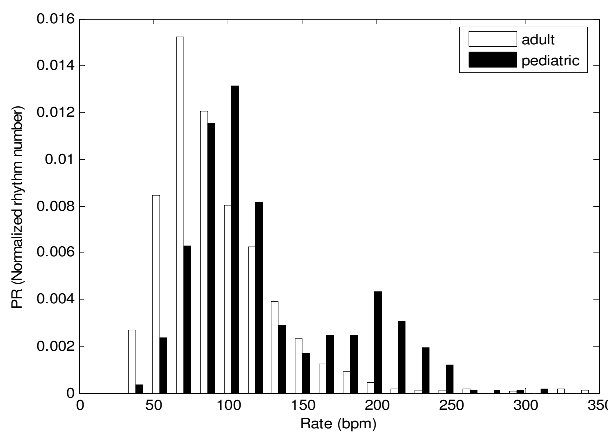

Figure 2. Comparison of the Pulse Rate parameter for nonshockable rhythms in adult and pediatric databases.

4. Discussion and conclusions

This study assesses the parameters that define the specificity of an AED classification algorithm. A comparative analysis has been performed considering adult and pediatric databases. The adult database comes from previous studies, while the pediatric samples have been exclusively supplied by Spanish hospitals for this study.

The analysis algorithm of a commercial AED has been tested. This algorithm was validated with the adult database, exceeding the AHA goals. But very important differences have been obtained when being tested with the nonshockable pediatric rhythms. Although all the NSR samples were correctly classified, 100% specificity; for the other nonshockable rhythms, a specificity of 78.97% was obtained for the complete pediatric database, and 69.73% for the subgroup of >1 year and <8 years of age. Results that are quite far from the AHA goal of 95%. These results differ from those obtained in previous studies [3, 4], where the algorithm designed for adult subjects was adequate for pediatrics.

The statistical analysis of the four characteristic parameters that determine the AED algorithm shows significant differences between the pulse rate distributions of adult and pediatric databases, being also significant for the other three. This explains the performance of the algorithm, as it is a decision tree based on the comparison of the 4 parameters with set thresholds. The first parameter considered in the tree is the pulse rate, which determines the comparative thresholds for the other three. These thresholds are more exigent for low PR in classifying a rhythm as shockable, and more relaxed when the PR is high compared to determined thresholds. The thresholds have been experimentally set according to the adult development database, and this study demonstrates that they are not adequate for the pediatric rhythms. Many pediatric SVTs show PR values that only shockable adult rhythm exhibit, and consequently, they can be easily classified as shockable by the algorithm. In conclusion, an algorithm like the one tested, which highly depends on the PR will fail in the correct detection of no ventricular rhythms presenting a high rate. A higher dependency on the morphology parameters should be pursued to make the algorithm adequate for adult and pediatric rhythms.

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