Age and Sex Dependent Criteria for Lower Limits of QRS Voltages

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Abstract

The aim of this study was to examine whether criteria for low QRS voltage should be age and sex dependent.

A database of 1496 normal ECGs from healthy adults was analysed using the University of Glasgow ECG analysis program. Correlation coefficients between peak-to-peak QRS voltages (ppQRS) and age were obtained. Differences in ppQRS due to sex were measured statistically. New thresholds were picked from the observations made and were tested on a second study population.

The lower limits of ppQRS for males were significantly higher than for females in leads V1 to V6 (p=0.031, exact binomial test). Lowering the threshold for abnormality in these leads to 0.8mV for females resulted in an increase in specificity from 99.7% to 99.9%.

There was evidence of correlation with age in males. In particular, the evidence supported using a different threshold for males under 40.

1. Introduction

Criteria for reporting low QRS voltages on electrocardiograms (ECGs) have been in use for many years. The presence of low voltages has been determined by using criteria with fixed thresholds – namely, that the QRS peak to peak deflection is less than 0.5mV in the limb leads or less than 1mV in the precordial leads. These same criteria are used for all patients, with diagnostic statements being output for low QRS voltages in the limb leads or in the precordial leads or in both sets of leads.

The effect of age, sex and race on abnormally high QRS voltages has been studied [1]. QRS voltages tend to increase until early adulthood and subsequently decrease. Lower QRS amplitudes in females are probably caused by higher fat content and the influence of breast tissue. With regard to race, precordial voltages in young Chinese men and women are lower than for a corresponding Caucasian population [2]. Age, sex and race have been incorporated into some diagnostic criteria. For example, the upper limits of normal voltage for R and S amplitudes in the diagnosis of right ventricular hypertrophy are age dependent. However, criteria for low QRS voltages do not generally include age, sex or race dependence as far as is known. A diagnosis of low voltage can be an indicator for pericardial effusion, COPD, obesity or pleural effusion [3]. There have been some concerns that low voltages are over-reported. There would seem to be no recognised basis for the accepted criteria for low voltages and it is probable that the thresholds originated from the convenience of 1mV being 2 boxes and 0.5mV being 1 box on the printed output. It was therefore decided to investigate low QRS voltages to see if they are age and sex dependent.

2. Methods

The database used for the study comprised 1496 normal ECGs from healthy adults (859 males and 637 females) aged 18-82 years. The study population was divided into 4 age-groups, 18-29, 30-39, 40-49, 50+. The distribution is shown in figure 1.

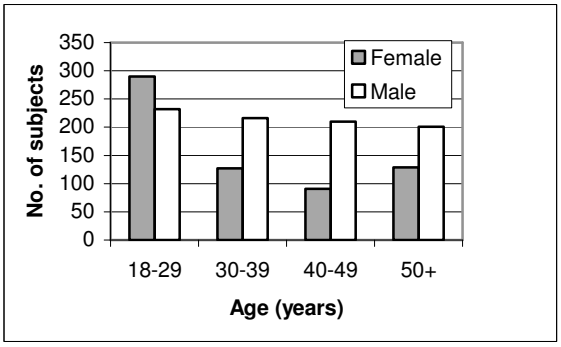

Figure 1. Age distribution within the normals study.

All of the ECGs were analysed using the University of Glasgow ECG analysis program[4]. The peak-to-peak QRS voltages for each lead were measured in the program from the peak of the R wave to the nadir of the S or Q wave, whichever was greater. These values were found for each lead and were extracted and input to statistical programs for analysis. The 2nd percentile of the distribution was taken as the lower limit of normal. If a limb or chest lead were unavailable, the ECG was excluded from the calculation of values for limb or chest leads, respectively. In order to model the case where the

values for leads I, II and III are all below a threshold, the 2nd percentile value of the **maximum** of ppQRS over these three leads was used. Similarly, the 2nd percentile value of the maximum of the peak to peak QRS voltages over leads V1-V6 was used. The difference in distributions for each lead between the male and female populations was compared using a Mann-Whitney test and the 2nd percentile values for female and male were compared using an exact binomial test. Dependence on age was investigated using Pearson's correlation.

New thresholds were picked from the observations made and were tested on a second study population, namely the CSE database[5]. The ECGs from 5 subjects under 18 years of age were excluded leaving 829 males and 386 females, predominantly aged 50 years and over. The distribution is shown in figure 2.

Figure 2. Age distribution within the CSE study.

3. Results

The lower limits of normal for the combinations of leads I,II and III and for leads V1 to V6 were found (Table 1).

Table 1. 2nd Percentile values for maximum of peak-to-peak QRS voltages of limb leads and of chest leads derived from 1496 normals.

LEAD	2nd Percentile (μV)		
	All	Female	Male
I, II, III	681	651	711
V1-V6	1243	1146	1504

The current thresholds of 500 and 1000μV for limb and chest leads respectively, used to report 'Low Voltage QRS' for males and females, are less than the 2nd percentile values. The relationship with sex was therefore investigated further.

The peak-to-peak QRS voltages have a skewed normal distribution (figure 3).

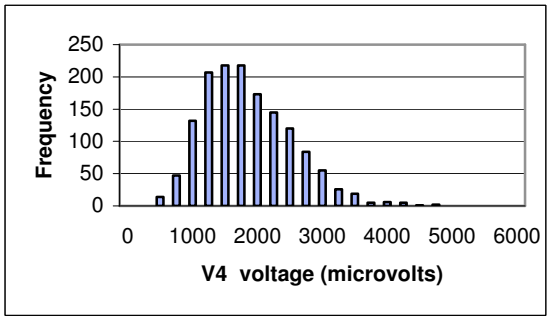

Figure 3. Distribution of peak-to-peak QRS voltages in lead V4 for the database of adult normal ECGs.

The Mann-Whitney test gave a significance of P=0.000 for differences due to sex in leads I, III and V1to V6. The difference just failed to reach significance at the 5% level for lead II (P=0.0513). The difference was significant for the combined leads I,II and III, and for the combined leads V1 to V6 (P=0.000 in both cases).

The 2nd percentile values for ppQRS were found for each lead (tables 2 and 3).

Table 2. 2nd Percentile values for peak-to-peak QRS voltages in the limb leads.

LEAD	2nd Percentile (microvolts)		
	All	Female	Male
I	363	337	372
II	488	530	447
III	189	183	194

Table 3. 2nd Percentile values for peak-to-peak QRS voltages in the chest leads.

LEAD	2nd Percentile (microvolts)		
	All	Female	Male
V1	503	489	518
V2	878	809	956
V3	737	632	934
V4	871	727	1125
V5	888	781	1017
V6	728	648	770

It can be seen that the 2nd percentile values for males in the six chest leads are all higher than for females and the significance of this was measured as p=0.031, using the exact binomial test.

There was insufficient data to use the same test for the limb leads.

Pearson Correlations were obtained against age for each lead and sex. Peak-to-peak QRS voltage gave a high correlation coefficient at P=0.000 for all leads excluding lead I for males. For females, the correlation was not significant ($P > 0.05$) for leads V3 to V5.

The 2nd percentile values for age groups 18-29,30-39,40-49 and over 50 years were calculated for the female and male groups for the limb leads (Tables 4 and 5) and the chest leads (Tables 6 and 7).

Table 4. 2nd percentile values of peak-to-peak QRS voltages in the limb leads by age for females.

Leads	Age Group			
	18-29	30-39	40-49	50+
I	330	306	444	349
II	651	547	496	494
III	204	203	183	157

Table 5. 2nd percentile values of peak-to-peak QRS voltages in the limb leads by age for males.

Leads	Age Group			
	18-29	30-39	40-49	50+
I	358	367	379	433
II	778	593	428	367
III	265	210	195	165

There is a trend of decreasing values with age in leads II and III, which is more evident for males.

Table 6. 2nd percentile values of peak-to-peak QRS voltages in the chest leads by age for females.

Leads	Age Group			
	18-29	30-39	40-49	50+
V1	517	515	618	427
V2	945	829	769	766
V3	694	619	466	714
V4	789	848	669	751
V5	771	835	750	857
V6	713	779	506	624

Table 7. 2nd percentile values of peak-to-peak QRS voltages in the chest leads by age for males.

Leads	Age Group			
	18-29	30-39	40-49	50+
V1	777	492	545	491
V2	1488	1130	1059	713
V3	1114	897	960	923
V4	1318	1201	997	1136
V5	1182	1053	1007	975
V6	862	877	740	761

There is evidence of decreasing trend in, for example, lead V2 but not in all leads.

The lower limits of normal for combined leads I,II and III were found for the 4 different age groups for males and females (Tables 8 and 9).

Table 8. 2nd percentile values of maximum of peak-to-peak QRS voltages of Leads I,II and III by age group.

	Age	18-29	30-39	40-49	50-59
Female		697	584	642	674
Male		923	787	672	680

Table 9. 2nd percentile values of maximum of peak-to-peak QRS voltages of Leads V1-V6 by age group

	Age	18-29	30-39	40-49	50-59
Female		1176	1167	1074	1150
Male		1798	1740	1393	1306

The lower limits of normal for the chest leads for males under 40 years old are markedly higher than those for males over 40.

There were no reports of low voltage in limb leads in the adult normal set using the existing criteria and only 4 reports of low voltage in the chest leads. In the CSE database, there were 35 reports of low voltage in the limb leads, 23 in the chest leads and 5 in both limb and chest leads.

Lowering the threshold for chest leads to 800μV for females resulted in 2 fewer reports of low voltage in the normal adults and a decrease of 12 (43%) in the CSE patients. In the chest leads, using a new threshold of 1300μV for males under 40 years of age resulted in 1 more report for the normal database but made no difference to the reports of low voltage in the CSE database. Raising this threshold to 1700μV for this subgroup gave a further 5 reports for the normal database and 9 more reports in the CSE database.

Raising the threshold to 600μV in the limb leads for those under 40 years of age resulted in 7 new reports of low voltage in the limb leads for the normals (all female) and 3 new reports in the CSE patients (1 female). Raising the threshold to 800μV for males under 30, gave a further 2 reports in the normals and also in the CSE set.

4. Discussion and conclusions

There is no recognised basis for the existing criteria used for reporting low voltages. It would seem that the current levels were used for convenience, as they are easy to apply and understand.

In the case of the chest leads, the thresholds do not take into account the significant difference due to sex. From Table 3 it can be seen that, for males, the current threshold of 1000μV will ensure that at least 2 of the values for individual leads will be below the lower limit of normal for those leads, as well as being below the lower limit of normal for the maximum of the chest leads, which is 1504μV (Table 1). Whereas, in the case of females, individual lead values may be above the lower

limit of normal for each lead but below the threshold of 1000μV, and a report of low voltage would still be given. For example, the ECG, shown in Figure 4, for a 41-year old female was reported as having low voltage complexes in the chest leads using current criteria when all individual chest leads have peak-to-peak voltages above the lower limits.

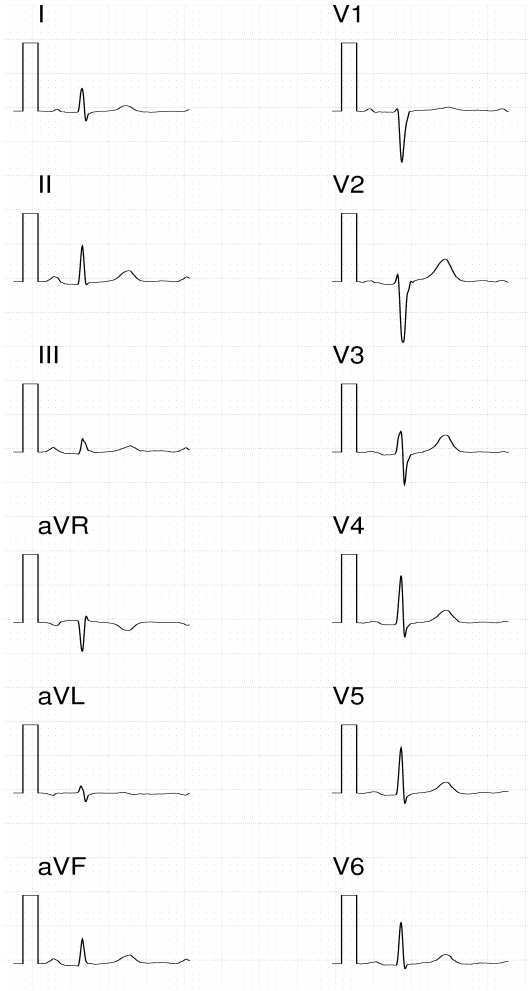

Figure 4. The median beats from an ECG of a 41-year old female where low QRS voltages are reported using a threshold of 1000μV. No report would be given if the threshold were reduced to 800μV.

The high values of the correlation coefficients with respect to age for males indicates that separate thresholds should be used for different age groups. Again, by considering the limits of normal for individual leads as well as the limit for the combination of leads, it was apparent that it might be appropriate to use higher thresholds for younger males. It is important to realise that there is no gold standard for reporting low voltages. Using higher thresholds for younger males will result in more reports of low voltage, which may not be acceptable in practice. There were insufficient numbers of young males in the CSE patient database (126 patients aged under 40) to test this thoroughly. Of these 126, 1 patient had all chest lead voltages less than 1000μV and 3 had values between 1500μV and 1600μV, with the remaining having higher voltages.

In conclusion, the current threshold used to determine low voltage in the chest leads does not reflect the evident dependence on sex and age. By lowering the threshold for women, the number of reports is significantly reduced. Raising the threshold for young males will result in more cases of low voltage in this group being reported, which otherwise could be overlooked. This may be a matter of preference on the part of reporting clinicians.

It may also be a matter of debate whether low voltages should be reported on paediatric ECGs. Further investigations are required to study whether the thresholds are appropriate for all races.

References

[1] Macfarlane PW, Lawrie TDV. The normal electrocardiogram and vectorcardiogram, In Macfarlane PW,Lawrie TDV,eds. Comprehensive Electrocardioology, Oxford:Pergamon Press 1989,407.

[2] Macfarlane PW, Chen CY,Chiang BN, Comparison of the ECG in healthy Chinese and Caucasians. In: Ripley K, ed. Computers in Cardiology 1987;14;143-146

[3] Bruch C, Schermund A, Dagnes N, Bartel T, Caspari G,Sack S, Erbel R,.Changes in QRS voltage in cardiac tamponade and pericardial effusion: reversibility of percardiocentesis after pericardiocentesis and after anti-inflammatory drug treatment. J Am Coll Cardiol 2001 Jul;38(1):219-26

[4] Macfarlane PW, Devine B, Clark E. The University of Glasgow (Uni-G) ECG Analysis Program. In Computers in Cardiology 2005;32:451-454

[5] J.L. Willems, C. Abreu-Lima, P. Arnaud *et al.*, The diagnostic performance of computer programs for the interpretation of electrocardiograms. *N Engl J Med* **325** (1991), pp. 1767–1773

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