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Heart Rate, PR, and QT Intervals in Normal Children: A 24-Hour Holter Monitoring Study

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Summary: A dynamic electrocardiographic Holter monitoring study was performed in 32 healthy children (20 males and 12 females, age range 6–11 years old), without heart disease, according to clinical and noninvasive instrumental examination. We evaluated atrioventricular conduction time (PR), heart rate (HR), and QT interval patterns defining the range of normality of these electrocardiographic parameters. The PR interval ranged from 154 ± 10 ms (mean $\pm$ SD) for HR ≤ 60 to 102 ± 12 ms for HR ≥ 120 (range 85–180). The absolute mean HR was 87 ± 10 beats/min (range 72–104), the minimum observed HR being 61 ± 10 (range 51–79), the maximum 160 ± 20 beats/min (range 129–186). Daytime mean HR gave a mean value of 93 ± 10 (range 71–148), while during night hours it was 74 ± 11 (range 54–98). The minimum QT interval averaged 261 ± 10 ms for HR > 120 and the maximum 389 ± 9 ms for HR ≤ 60; the corresponding mean value of QTc (i.e., QT corrected for HR) ranged from 388 ± 8 for HR ≤ 60 beats/min to 403 ± 14 ms for HR > 120 beats/min. The results of the present study provide data of normal children which can be readily compared against those of subjects in whom cardiac abnormalities are suspect or patent. Some of the data reported here differ from those currently available, as for PR and HR, obtained from standard resting electrocardiogram, and cast doubt on the usefulness of correcting for HR in the QT interval in these subjects.

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Introduction

Standard 12-lead resting electrocardiography (ECG) does not allow long-term monitoring and His bundle electrocardiography does not permit obtaining data from selected subjects for whom an electrophysiologic study is deemed inadvisable.

The present study investigated healthy children, undergoing ambulatory ECG Holter monitoring (AEM),[1,2] in order to obtain data on heart rate (HR), PR interval, and QT interval patterns of cardiac activity recorded over a 24-h period.

Materials and Methods

Population

Thirty-two children, 20 males and 12 females, aged 6 to 11, underwent AEM. Twenty children were volunteer subjects, the others had requested an examination prior to taking up a sports activity. None of the children presented any abnormality upon a physical and noninvasive instrumental examination (phonocardiography and carotid pulse, M-mode, and two-dimensional echocardiographic study).

ECG Recording

The recording system (Hittman Compact IV) had two channels, corresponding to two leads, chosen on the basis of the 12-lead resting ECG, one of which corresponded to the lead in which the P wave was best represented, the other to the lead in which the QT interval was longest. All the recordings began at 6.00 P.M., plus or minus 15 min at the most.

ECG Analysis

The scanning system (Hittman Compu Scan III) permitted a high-speed computerized reading (240 times real-time) of the data recorded. The final printout allowed us to have data on the heart rate pattern for every hour as well as the mean per 24-h HR. After printing out, ECG strips, lasting at least 16 s and with a HR which had been steady for at least 5 min, were recorded at a paper speed of 50 mm/s. Five categories were considered: HR ≤ 60 beats/min, HR ranges of 61–80, 81–100, 101–120, and > 120 beats/min.

Analysis of the PR Interval

For each of the HR groups considered, we had collected at least 10 ECG strips obtained at different hours. On the basis of these, we measured the PR interval on eight consecutive beats and calculated the mean. In the event the two channels gave different PR values, we considered the longest value.

HR Analysis

From the printouts obtained during scanning we calculated the mean HR of the first hour, second hour, third hour, and so on. We then calculated the total mean HR, obtained by adding up the mean per 24 h of all the subjects and dividing the value obtained by the number of subjects; the mean daytime and nighttime HR, considering night to be the period from 11.00 P.M. to 7.00 A.M., and finally the mean minimum and maximum HR, obtained from the minimum and maximum values in each subject over a period of six consecutive beats.

Analysis of the QT Interval

The QT interval was measured in the different HR groups on eight consecutive beats. A mean value was then calculated. When it proved difficult to establish the terminal limb of the T wave, the QT interval was measured from the beginning of the Q wave to the intersection between the tangential line over the terminal limb of the T wave and the isoelectric line.[3] The QTc was obtained by dividing the QT, expressed in seconds, by the square root of the interval R-R, which also was expressed in seconds.[4] The QT interval corrected for heart rate (QTc) was calculated for the different HR groups, according to the methods described for the PR and QT intervals.

All the values are expressed in mean ± standard deviation (SD).

Results

The PR values range from 154 ms (10 SD) for HR ≤ 60 beats/min, to 102 ms (12 SD) for HR > 120 beats/min (Fig. 1). The minimum value observed was 85 ms, the maximum 180 ms.

Figure 2 illustrates the heart rate pattern over the 24-h period: the mean value of the first hour is 96 beats/min (13 SD). This value gradually falls until a minimum mean value of 70 beats/min (11 SD) is reached at the tenth hour, which corresponds to 3.00 A.M. It then begins to rise again until a maximum mean value of 102 beats/min (17 SD) is reached at the seventeenth hour, which corresponds to 10.00 A.M.

The absolute mean HR per 24 hours was 87 beats/min (10 SD) (range 72–104), the nighttime mean 74 beats/min (11 SD) (range 54–98), daytime mean 93 beats/min (10 SD) (range 71–148); the minimum mean HR was 61 beats/min (10 SD) (range 51–79), the maximum mean HR 160 beats/min (20 SD) (range 129–186) (Table I).

The QT interval gave a minimum mean value of 261 ms (10 SD) for HR > 120 and a maximum mean value of 389 ms (9 SD) for HR < 60 beats/min (Fig. 3).

The QTc gave values ranging from 388 ms (8 SD) for HR < 60 beats/min to 403 ms (14 SD) for HR > 120 beats/min (Table II).

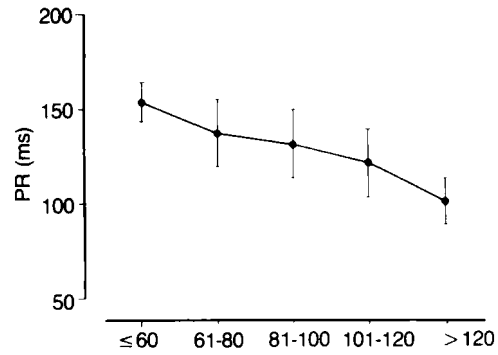

FIG. 1 Atrioventricular conduction time (PR) in the five groups of heart rate (HR) (beats/min) considered. Values are mean ± SD.

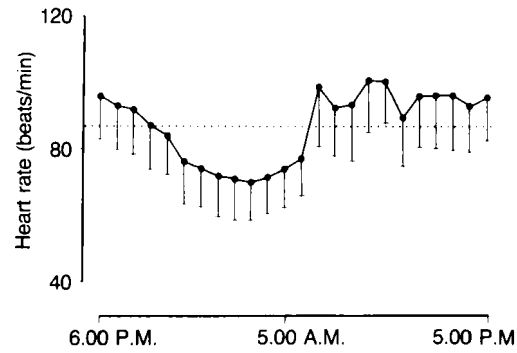

FIG. 2 Hourly mean values of heart rate (HR) (beats/min). The dotted line represents absolute mean heart rate. Values are mean ± SD.

TABLE I Spectrum of heart rate in 32 normal children

	Mean ± SD (beats/min)	Range (beats/min)
Overall monitoring period		
Average	87 ± 10	72-104
Minimum observed	61 ± 10	51-79
Maximum observed	160 ± 20	129-186
Daytime period	93 ± 10	71-148
Nighttime period	74 ± 11	54-98

TABLE II Spectrum of QTc (QT interval corrected for heart rate) in 32 normal children

Heart rate (beats/min)	QTc ms (mean ± SD)
≤60	388 ± 8
61-80	388 ± 21
81-100	404 ± 24
101-120	409 ± 19
>120	403 ± 14

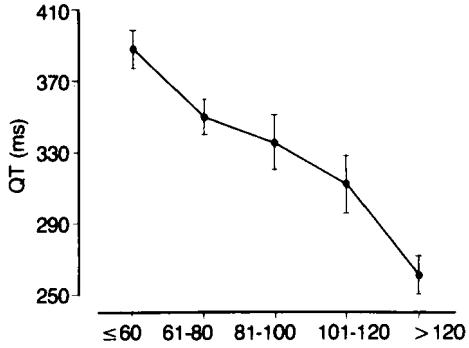

FIG. 3 The QT interval in the five groups of heart rate (beats/min) considered. Values are expressed as mean ± SD.

Discussion

Ambulatory electrocardiographic monitoring has been widely used recently to study cardiac arrhythmias and other forms of conduction abnormality. However, studies carried out with AEM and aimed to define heart rate, rhythm, and conduction patterns in normal subjects, both adults[5-7] and children,[8,9] are not numerous.

As far as the various age groups of children are concerned, the age group which has been most widely studied, even with the use of AEM, and above all with reference to the QT interval, which seems to play a role in the sudden infant death syndrome (SIDS),[10,11] is that of newborn infants.[12,13]

The age range considered in this study is 6-11 years. One of the few studies employing the AEM technique in this age group is that of Southall *et al.*,[9] who examined 104 normal children between 7 and 11 years old.

These authors calculated the average, maximum, and minimum HR; they also observed the presence of junctional escape rhythms, supraventricular premature beats, sinus pauses, and first degree atrioventricular (AV) blocks. Our aim in adopting AEM in this study was to observe the patterns of three important parameters (HR, PR, and QT intervals); no data on PR interval values in normal children, using AEM, appear in the literature. In fact, the values of this parameter, namely the intraatrial, AV nodal, and His-Purkinje conduction[14] have all been obtained from studies carried out with the standard resting ECG[15,16] and intracardiac[17] techniques. AEM does offer an important advantage: it permits the observation of electrocardiographic parameters under conditions which are much closer to physiological conditions, especially as far as children are concerned. The results of our study show that the maximum observed PR value was 0.18 s, a value which we believe is the maximum limit in a child whose age falls within the pertinent age group. This value, however, contrasts with what is deemed to be the maximum PR limit, that is 0.20 s.[15] On the other hand, we must consider the rather small number of subjects studied, even though we gathered, developed, and studied a large number of observations for each one of them. Another fact to be borne in mind is the objective difficulty of carrying out AEM on these subjects.

This is, in fact, a major limitation and is probably the reason there are so few studies on large population. The HR pattern does not call for any particular comment, except one which is quite obvious. It presents absolute mean values and daytime and nighttime mean values lower than those of subjects belonging to lower age groups and higher than those of adults. Of note is that the absolute mean value of HR (87 beats/min) is almost identical to the one observed in a study carried out, with traditional electrocardiography, on subjects in the age range of 6-14 years.[18] In that study, however, the minimum and maximum values are very far from those obtained in our study.

As far as the QT interval (that reflects, within limitations, the duration of depolarization and repolarization)[14] is concerned, this parameter is almost always given as a value corrected for heart rate (QTc). The correction is generally made by applying Bazett's formula,[4] the validity of which has been questioned. In particular, it has been demonstrated to be inadequate in adults during a high HR induced by exercise or pacing,[19,20] and it has also been proved that it overcorrects high HR and undercorrects low HR.[21] To explain this inadequacy of the Bazett's formula, it can be hypothesized that factors other than heart rate may have some influence on the duration of the electric systole.[20,22,23]

In light of these considerations, we decided to calculate separately the QT (Fig. 3) and the QTc (Table II). It seems possible that pure data obtained from a normal population represent a better frame of reference when the issue is to establish whether a value found is to be considered pathological or not.

In conclusion, the results of this study provide data from normal children which can be readily compared to data from subjects in whom cardiac abnormalities are suspected.

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