นิพนธ์ต้นฉบับ

Linear regression formula for correction of the QT interval of heart rates in children

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The QT interval is beneficial in clinical practice because of its value in detecting and measuring abnormalities in the physiologic state of the cardiac conduction system, as well as organic changes in the heart muscle itself. Among the many physiological and pathological factors that contribute to the QT interval, heart rate plays the major role. To evaluate the correlation between the heart rate (RR interval) and QT interval, the QT and RR interval were measured on the standard 12-lead electrocardiograms of 170 children (97 boys and 73 girls) at the Department of Pediatrics of Chulalongkorn Hospital. The mean age was 5.93 ± 4.96 years (range from 5 days to 15 years). The RR interval, heart rate and QT interval were 0.58 ± 0.13 second (range 0.36 to 0.98 second), 108.93 ± 24.57 beats per minute (range 61 to 168 beats per minute),

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and 0.31 ± 0.04 second (range 0.25 to 0.42 second), respectively. The linear regression model yielded a correction formula of QT_{LC} = QT +1/4(1-RR). The mean QT_{LC} was 0.41± 0.02 second (range from 0.40 to 0.42 second). The mean QT_{LC} values are virtually constant across the range of RR intervals. This linear correction formula of the QT interval has the same reliability as Bazett's formula but it is more practical and easier in calculation for clinical use.

Key words: *QT interval, Children.*

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วรนุช จงศรีสวัสดิ์, ไพโรจน์ โชติวิทยธารากร, โชติมา ปัทมานันท์, จุล ทิสยากร, วิโรจน์ สืบหลินวงศ์. การปรับค่าระยะเวลา QT ในเด็กโดยสมการเส้นตรง. จุฬาลงกรณ์เวชสาร 2539 กุมภาพันธ์; 40(2): 123-131

ค่าระยะเวลา QT ในคลื่นไฟฟ้าหัวใจมีความสำคัญในทางคลินิก สามารถบอกถึงความผิดปกติในการเปลี่ยนแปลงศักดาไฟฟ้าของกล้ามเนื้อหัวใจหรือโรคหัวใจบางชนิด ผู้รายงานได้ทำการศึกษา ถึงวิธีการในการปรับค่าระยะเวลา QT (corrected QT interval)ในเด็ก โดยศึกษาจากผลบันทึกคลื่นไฟฟ้าหัวใจปกติของผู้ป่วยเด็กที่มารับการตรวจที่ภาควิชากุมารเวชศาสตร์ โรงพยาบาลจุฬาลงกรณ์ จำนวน 170 ราย เป็นชาย 97 รายและหญิง 73 ราย มีอายุระหว่าง 5 วันถึง 15 ปี (5.9 $\pm$4.96 ปี) ค่าระยะเวลา RR อัตราการเต้นของหัวใจและค่าระยะเวลา QT มีค่าระหว่าง 0.36 - 0.98 วินาที (0.58 $\pm$ 0.13 วินาที), 61-168 ครั้งต่อนาที (108.93 $\pm$ 24.57 ครั้งต่อนาที) และ 0.25 - 0.42 วินาที (0.31 $\pm$ 0.04 วินาที) ตามลำดับ สมการเส้นตรงที่ใช้ในการปรับค่าระยะเวลา QT คือ $QT_{LC} = QT + 1/4 (1-RR)$ โดยค่า QT_{LC} มีค่าระหว่าง 0.40-0.42 วินาที (0.41 $\pm$ 0.02 วินาที) และมีการเปลี่ยนแปลงตามอัตราการเต้นของหัวใจใกล้เคียงกับการปรับค่าระยะเวลา QT โดยวิธีของ Bazett แต่มีความง่ายในการคำนวณและสะดวกในการนำมาใช้ในทางคลินิกมากกว่า

The clinical interpretation of change in the QT interval is a topic of growing interest in clinical practice. It's prolongation is associated with increasing risk for malignant ventricular arrhythmia and sudden death.[1-4] Among many physiological and pathological factors that contribute to the duration of the QT interval, heart rate plays the major role.[5-9] Many formul as have been used to adjust the QT interval for heart rate.[10-12] The most common and simplest method utilized is Bazett's square root formula. However the adequacy and validity of this approach to adjust for differences in heart rate has been questioned.[11,12] In 1992, Sagie et al, developed a linear regression equation (QT_{LC}) for correction of the QT interval in adult subjects (Framingham Heart Study), and this linear correction equation corrected the QT interval for heart rate more acurately than the square root equation of Bazett's formula.[13] The purpose of this study is to present the result of a linear regression equation for correction of the QT interval in children and to compare it with Bazett's formula.

Methods

Electrocardiograms to measure the duration of QT and RR interval were performed on 170 normal children whose ages were below 15 years and who had never received any cardiac drugs. Measurements were obtained from 12-lead, resting electrocardiograms, with a paper speed of 25 millimeter/second. All of the electrocardiograms, selected were in sinus rhythm. The QT and RR intervals were measured manually with the aid of a caliper and magnifying lens. The duration of the QT interval was measured from the beginning of the QRS complex to the end of the T wave when its terminal limb joined the baseline.[14] The duration of the RR interval was measured from the tip of the R wave which was used to measure the QT interval to the tip of next R wave.

Data analysis

The linearity of the QT-RR relation was tested for different forms of RR interval such as RR, $RR^{1/2}$, $RR^{1/3}$, log RR and log [10 (RR + 0.07)]. The X coefficient (regression slope) of the most reliable and simplest form of RR interval was selected and an RR interval of 1.00 was used as the reference point The linearly corrected QT equation is QT_{LC} = QT+X coefficient(1-RR). Although age and sex are factors that could influence the duration of the QT interval, Simonson and Moss found that these factors had little effect on the duration of the QT interval.[9,15] Therefore, we did not consider these factors in calculating the relation of QT-RR in our linear regression formula. Then we applied this equation and Bazett's formula to the data for each subject and plotted the mean values after grouping subjects by RR intervals. This method will indicate which equation will be more reliable in correcing the QT interval evenly across the range of RR values.

Results

The characteristics of the selected subjects are summarized in Table 1. The correlation

coefficient (r) between different forms of RR and QT intervals ranged from 0.92 - 0.93 (Table 2). The X coefficient of the second equation (0.264) was selected for the linear regression equation and modified to 0.25 or 1/4 for an easier calculation. Therefore, the linearly corrected QT (QT_{LC}) formula is : $QT_{LC} = QT + 1/4(1-RR)$ where QT and RR were the measured values.

The mean QT_C (Bazett's formula) and QT_{LC} are computed for RR decile (Table 3). The mean QT_{LC} value are virtually constant across the range of RR value similar to Bazett's formula (Figure 1.) Thus the linear correction for QT equation is a valid correction. The mean QT_C and QT_{LC} for children in this study is 0.40 ± 0.02 and 0.41 ± 0.02 respectively.

Table 1. Characteristics of the Study Population.

	Range	Mean	S.D.
Age (years)	0.015-15	5.93	4.96
Heart rate (beat/min.)	61-168	108.93	24.57
RR interval (sec)	0.36-0.98	0.58	0.13
QT interval (sec)	0.25-0.42	0.31	0.04

Table 2. The linear regression equation and correlation coefficient of QT and RR interval in different forms of RR

Equation	r	SEM
$QT = 0.396 + 0.36 \log RR$	0.93	0.011
$QT = 0.153 + 0.264\ RR$	0.92	0.009
$QT = 0.4\ 12\ RR^{1/2} - 0.005$	0.93	0.013
$QT = 0.565\ RR^{1/3} - 0.163$	0.93	0.017
$QT = 0.406 \log [(10\ RR + 0.07)] - 0.02$	0.93	0.013

Table 3. Mean QT,QT_C and QT_{LC} at different decline of RR interval in children.

RR interval	Subject	Mean QT	Mean QT_C	Mean QT_{LC}
0.36-0.40	13	0.241 ± 0.016	0.397 ± 0.026	0.399 ± 0.016
0.41-0.45	17	0.268 ± 0.016	0.408 ± 0.017	0.410 ± 0.011
0.46-0.50	22	0.282 ± 0.015	0.404 ± 0.018	0.410 ± 0.013
0.51-0.55	27	0.294 ± 0.014	0.404 ± 0.018	0.411 ± 0.013
0.56-0.60	31	0.309 ± 0.015	0.406 ± 0.017	0.414 ± 0.013
0.61-0.65	15	0.319 ± 0.012	0.402 ± 0.015	0.412 ± 0.012
0.66-0.70	14	0.330 ± 0.016	0.402 ± 0.019	0.411 ± 0.016
0.71-0.75	15	0.350 ± 0.013	0.412 ± 0.015	0.413 ± 0.013
0.76-0.98	16	0.373 ± 0.018	0.404 ± 0.002	0.409 ± 0.022

Discussion

Assessment of the heart rate adjusted QT interval is considered to be clinically important. Heart rate corrected QT is used to predict life threatening arrhythmias, sudden death, or to diagnose and study the physiological and pathological conditions that interfere with the QT interval.[1-4,16] It would be appropriate to use a QT correction formula that accurately corrects the QT interval. Several approaches had been purposed to adjust the QT interval for heart rate,[10-12] and the most frequently used has been Bazett's square root formula which was introduced more than seventy years ago. In adult populations this formula overcorrects the measured QT interval at fast heart rates and undercorrects it at slow heart rates[11,12] But in our data our formula reliably corrects the QT across a wide range of RR cycle lengths and the linear correction equation corrects the QT interval as reliably as Bazett's formula (Figure 1).

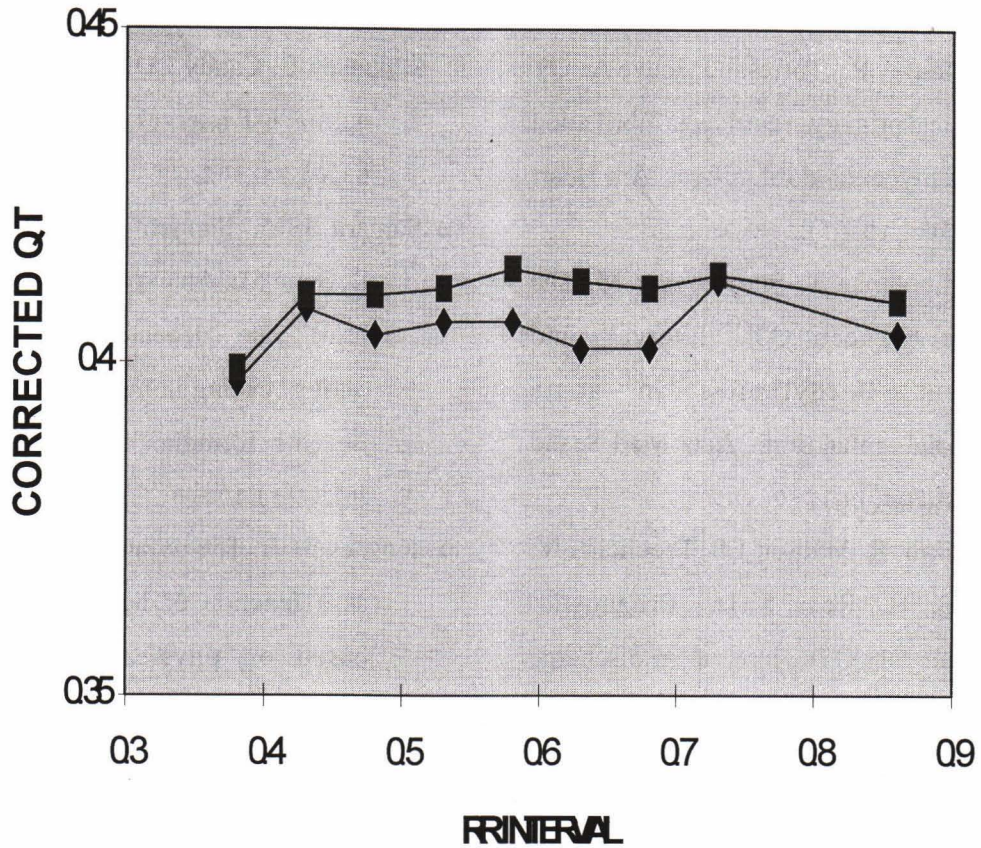

Figure 1. Mean corrected QT values from Bazett's formula and from the linear regression equation are plotted for each of RR interval. Mean QT_c (+) and QT_{LC} (-) values are virtually constant across the range of RR interval.

The adequacy of the linear regression model is not inferior to Bazett's formula but it is more practical and easier for calculation. Therefore, this equation may be chosen as a suitable simple equation that could be used conveniently in clinical practice. The limitation of this study is that the QT measurements were collected from resting electrocardiograms. We did not have the option to test whether this linear model can be applied at extreme values of heart rate because the QT interval is related not only to heart rate but also to several factor such as changes in autonomic nervous tone and metabolic factors.[16-18] Aditional research is warranted to determine if linear correction of the QT interval is suitable for these situations.

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