ORIGINAL ARTICLE

ECG PATTERN IN PAEDIATRIC POPULATION OF WESTERN RAJASTHAN

Surendra Parihar, ND Soni, Raghuveer Choudhary, VK Chawla, Jayant Kumar, Kamala Choudhary
Department of Physiology, Dr. S. N. Medical College, Jodhpur India

Background: The ECG pattern in paediatric population varies with age and sex. The majority of changes occur during the first year of life due to changes in cardiac anatomy and haemodynamics soon after birth, as a result of the cessation of placental circulation and establishing cardio-pulmonary circulation. Therefore the majority of normal adult values cannot be used in the newborn. **Methods:** This study was carried out in 200 children, with equal males and females, divided into 5 age groups from 0–14 years. Single chest lead ECG machine with standard setting (10 mm/mV. with a standard paper speed of 25 mm/sec.) was used in the study for recording of ECG. The electrocardiogram was recorded in all 12 leads and carefully interpreted for heart rate, rhythm, intervals and duration for evaluation of developmental, age and sex related changes. **Results:** The heart rate was increased in first 1–2 month of age and then in the following 6 months it remained stable and then slowly declined after 1 year of age. Heart rate attained adult value at the 12–14 years of age. The PR interval correlated with heart rate and with age. PR interval progressively and significantly increased with age and decreased with heart rate up to 4 year of age. Duration of QRS increased with age; in new born infants ranging from (37–80 ms) and 75 ms at the age of 6–14 years. Mean QRS duration was greater for boys than for girls in most age groups, but the difference in upper limits of normal was small, ranging from 2 to 7 ms. Mean value of QTc interval was not significantly changed with age as compared to heart rate. We found an upper limit of the normal QTc interval as 523 ms which is higher than the commonly used criterion of 440 ms. Significant gender differences were demonstrated for amplitude and QRS duration. **Conclusion:** Normal limits of many ECG measurements in our study were different from those reported earlier. These findings are clinically significant and suggest that diagnostic criteria for the paediatric ECG should be adjusted. These gender specific ECG parameters are useful for the interpretation of paediatrics ECG.

Keywords: ECG patterns, paediatric age, Western Rajasthan

INTRODUCTION

Interpretation of paediatric electrocardiograms (ECGs) can be challenging for the emergency room physician. Part of this difficulty arises from the fact that the normal ECG findings, including heart rate, rhythm, axis, intervals and morphology changes from the neonatal period through infancy, childhood, and adolescence. These changes occur as a result of changes in cardiac anatomy and haemodynamics, soon after birth due to cessation of placental circulation and establish the cardio-pulmonary circulation and the maturation of the myocardium and cardiovascular system with age.[1]

The knowledge of the normal variation of ECG measurements with age is essential for proper interpretation of the paediatric ECG. Some of the previous studies mainly carried out in white population have shown discrepancy in their normal limits. Further it will be inappropriate to apply their normal values to non white individuals. In this study, ECGs were recorded at a relatively low sampling rate, and ECG measurements were done manually.

MATERIAL AND METHODS

The present study was carried out with 200 healthy or apparently healthy paediatrics age groups subjects (0–14 years). Male and female subjects were equal in number. The children with previously known cardiovascular abnormalities were excluded from the study. Total subjects were divided into five age groups. Group I was for 0–1 month, Group II for 1 month–1 yr, Group III for 1–4 yr, Group IV for 4–6 yr, while Group V was for 6–14 yr of age. All children up to 1 month of age were combined in one group, because of the relatively small sample size. Each group was subdivided to subgroup according to gender.

The single chest lead ECG machine with standard setting (10 mm/mV, paper speed 25 mm/sec) was used in the study for recording of ECG tracing. The electrocardiogram was recorded in all 12 leads and carefully interpreted for heart rate, rhythm, intervals and duration for evaluation of developmental, age and sex related changes. The normal limit (value) established by Davignon *et al*[2], 1979 was used as reference value for the interpretation of the ECG.

For each child, weight, height, physical and clinical examination was done prior to recording the ECG. Data for weight and height corresponded well with the WHO/API growth standard. The study was approved by the local ethics committee.

RESULTS

The mean values are given together with the 98th percentiles, taken as the upper limits of normal and the 2nd percentiles, taken as the lower limits of normal. Zero amplitude values indicating absent Q, R, or S waves, were also included in the statistical analysis of the data, Normal limits are presented separately for boys (upper row) and girls (lower row) to indicate sex differences. (Table-1 and Table-2).

The mean value of the heart rate in male new born ranged from (110 -165)133 beat /min and (107–178) 135 beat/min at the age of 1 year and (61–118) 88 beat/min at 12–16 year of age, while in female new born it ranged from (103–163) 132 beat/min to (102–173) 136 beat/min at 1 year of age and 81 (58–100) at 12–16 year of age. Heart rate substantially decreases with age as illustrated in Table-1.

The heart rate was increased in first 1–2 month of age may be due to small stroke volume in early stage of infants. During the following 6 months, it remained rather stable and then slowly declined after 1 year of age due to maturation of vagal innervations of the sinus node or increased muscles mass with age.

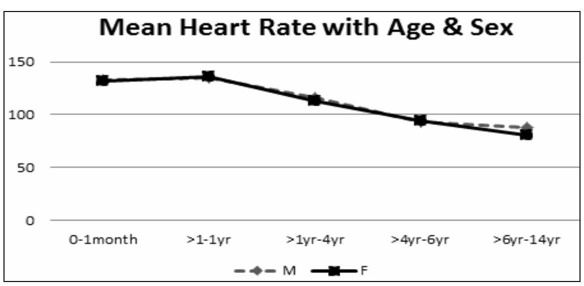

Figure 1: Mean Heart Rate with Age and Gender

The mean value of PR interval in male new born ranged from (0.06–0.16) 0.09 sec. to (0.065–0.136) 0.085 sec. at the age of 1 year and 0.13 sec. (0.12–0.15) sec at 6–12 year of age, while in female new born it ranged from (0.06–0.16) 0.09 sec to (0.05–0.17) 0.10 sec at the age of 1 year and 0.12–0.16) 0.13 sec at 6–12 year of age.

The normal PR interval duration was shorter in children may be due to smaller cardiac muscle mass and progressively increased with age from birth to the age of 2–4 years. And attained the normal adult value at the age of 6 years 0.10–0.16 (0.13) sec.

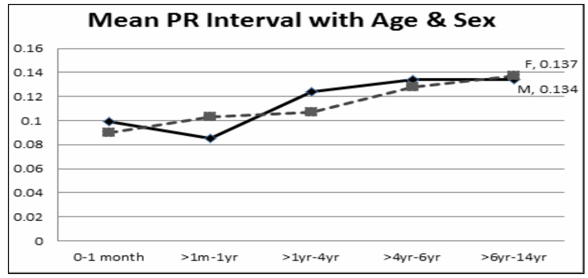

Figure-2: Mean PR interval

The normal values for QRS complex duration was observed in lead V5 is displayed in Table-1. The QRS morphology in newborn had more notches as compared to older children and adults. The normal QRS duration was increased with age, as the ventricular muscles mass increases with age.

In new born infants, the mean QRS duration ranged from (37–80) 54 ms and 75 ms at the age of 6–14 years. The mean QRS duration is greater for boys than for girls in most age groups, but the differences in upper limits of normal was small, ranging from 2 to 7 ms.

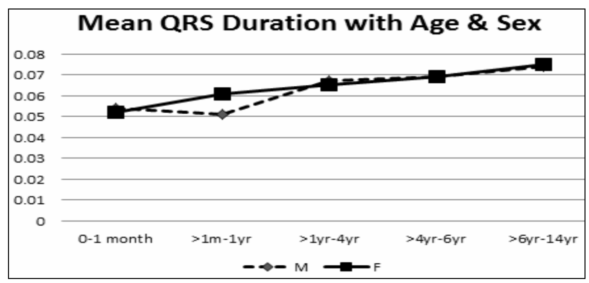

Figure-3: Mean QRS duration

The mean value of Q-T interval (QTc) in new born ranged from 317–432 ms (375 ms) and 303–410 ms in infants while in adolescence 361–523 ms (410 ms) as shown in Table-1b. So, the mean value of QT interval was not significantly changed with age as compared to heart rate.

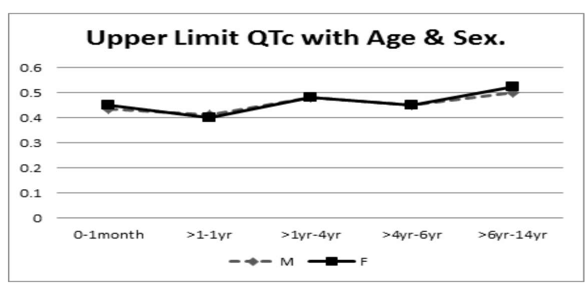

Figure-4 Upper limit QTC

The Q-wave amplitude is presented for clinically important leads III and V6 in Table-2. The upper limit of the normal Q-wave amplitude in first month of life 0–4 mm in lead III and 0–2 mm in lead V6, linearly increased with age to a maximum between 1 and 3 years, then after decreased towards the initial value.

The upper limit of the Q wave amplitude in 6–12 year age group was 0.30mv in male and 0.18 mV in female subjects shows that the girls have significantly lower upper limits of the normal Q-wave amplitude in V6 and V7 as compared to boys.

The mean values of R/S ratio in right precordial leads V1 was 1.54 in male newborn and 1.90 in female. It was found more than one and it decreased significantly with the increase in age from neonatal period and infants up to toddlers as shown in Table-2. The right precordial leads show right ventricular dominance and the pattern was Rs in spite of rS in adults.

The mean values of R/S ratio in left precordial leads V5 and V6, was increased significantly, with the increase in age up to the age of 2–4 years and the pattern was Rs with the persistent of deep S-wave in that leads till the age of 6 years.

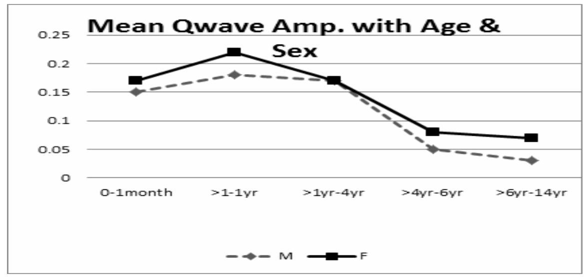

Figure-5: Mean Q wave Amplitude

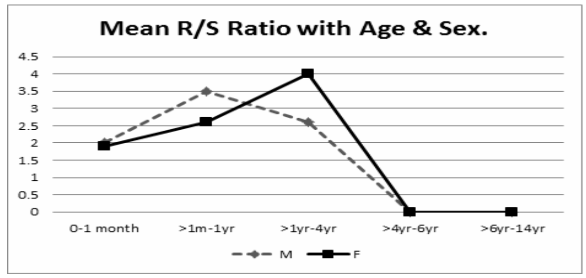

Figure-6: Mean R/S Ratio

Table-1: Normal range of Heart rate, PR interval and QRS with relation to age and sex on the resting 12 leads ECG

Groups	Gender	Heart Rate (bpm)	PR Interval (lead II)	QRS/Sec (lead V5)
Group1 (0–1 month)	Male (N=20)	110–165 (133)	0.065–0.209 (0.099)	0.037–0.080 (0.054)
	Female (N=20)	103–163 (132)	0.066–0.164 (0.090)	0.030–0.076 (0.052)
Group 2 (>1 m–1 yr)	Male (N=20)	107–178 (135)	0.065–0.136 (0.085)	0.024–0.074 (0.051)
	Female (N=20)	102–173 (136)	0.051–0.172 (0.103)	0.040–0.092 (0.061)
Group 3 (>1–4 yr)	Male (N=20)	100–141 (116)	0.087–0.152 (0.124)	0.040–0.092 (0.067)
	Female (N=20)	88–150 (113)	0.066–0.164 (0.107)	0.035–0.092 (0.065)
Group 4 (>4–6 yr)	Male (N=20)	70–115 (93)	0.107–0.168 (0.134)	0.040– 0.092 (0.069)
	Female (N=20)	75–115 (94)	0.086–0.168 (0.128)	0.060–0.092 (0.069)
Group 5 (>6–14 yr)	Male (N=20)	61–118 (88)	0.127–0.152 (0.134)	0.060– 0.100 (0.074)
	Female (N=20)	58–100 (81)	0.129–0.160 (0.137)	0.060–0.110 (0.075)

First values represent 2nd percentile and second values represent 98th percentile. Values in parenthesis represent mean value of ECG parameters.

Table-2: Normal range of QTc, Q wave amplitude and R/S ratio in relation to age and gender on the resting 12 leads ECG

Groups (Age)	Gender	QTc/Sec (Lead V5)	Q wave Amp		R/S RATIO	
			(Lead III)	(Lead V6)	(Lead V1)	(Lead V6)
Group1 (0–1 month)	Male (N=20)	0.317–0.432 (0.375)	0.2–0.4 (0.15)	0–0.2 (0.08)	0.560–2.81 (1.54)	0.29–9.3 (2.0)
	Female (N=20)	0.310–0.449 (0.363)	00–0.3 (0.17)	0–0.2 (0.08)	0.698–4.00 (1.90)	0.39–5.2 (1.9)
Group 2 (>1 m–1 yr)	Male (N=20)	0.303–0.410 (0.349)	0.12–0.28 (0.18)	0–0.2 (0.12)	0.440–1.93 (1.13)	0.46–8.6 (3.5)
	Female (N=20)	0.303–0.400 (0.349)	0.11–0.3 (0.22)	0.03–0.23 (0.15)	0.566–2.00 (1.21)	0.70–6.0 (2.6)
Group 3 (>1–4 yr)	Male (N=20)	0.373–0.480 (0.424)	00–0.3 (0.17)	0–0.3 (0.15)	0.500–2.80 (1.13)	1.0–6.8 (2.6)
	Female (N=20)	0.307–0.480 (0.400)	00–0.33 (0.17)	0–0.31 (0.15)	0.179–1.63 (0.847)	0.73–11 (4.0)
Group 4 (>4–6 yr)	Male (N=20)	0.357–0.450 (0.410)	00–0.2 (0.05)	0–0.26 (0.12)	0.130–3.43 (0.960)	U–U
	Female (N=20)	0.386–0.450 (0.420)	00–0.2 (0.08)	0–0.23 (0.10)	00–1.10 (0.670)	U–U
Group 5 (>6–14 yr)	Male (N=20)	0.476–0.500 (0.436)	00–0.16 (0.03)	0.01–0.3 (0.12)	0.476–6.40 (1.23)	U–U
	Female (N=20)	0.361–0.523 (0.410)	00–0.18 (0.07)	0–0.18 (0.07)	0.184–1.43 (0.698)	U–U

First values represent 2nd percentile and second values represent 98th percentile. Values in parenthesis represent mean value of ECG parameters.
U= unable to detect

DISCUSSION

In our study the mean value of heart rate in male newborn ranges from 110–165 (133) beat/min and 107–178 (135) beat/min at the age of 1 year and 61–118 (88) beat/min in adolescence. These observations were almost similar to the study of Devignon *et al*[2] who observed 91–166 (129) beat/min heart rate in infants and 60–119 (85) beat/min at the age of 12–14 year. Sharieff *et al*[3] observed 90–160 beat/min in infants and 110–170 beat/min at the age of 1year and 65–130 beat/min in adolescence (12–15 years). Venkatesh *et al*[4] observed 90–160 beat/min in infants and 50–120 beat/min in adolescence. Our results are lower than the study of Rijnbeek *et al*[5] who observed mean value of heart rate in new born ranging 129–192 (160) beat/min and 106–194 (128) beat/min at the age of 1year.

All these studies are in agreement and corroborate with our study in reference to that the mean value of the heart rate in most age group (from neonate to adolescence) are almost similar but some discrepancy in upper limit is present due to small sample size and manual interpretation of ECG. While Rijnbeek *e tal*[5] used large sample size and computerised data.

All these studies also corroborate with our study that the heart rate was increased in first 1–2 month of life and then during and following 6 months, it remains rather stable and then slowly declines after 1 year of age and attained the adult value at the 12–14 year of age.

In our study the mean value of PR interval in male new born ranges from (0.06-0.16) 0.09 sec and 0.085 (0.065–0.136) sec at the age of 1 year and 0.13 sec (0.12–0.15) at 6–14 year of age was very similar to the study of Devignon *et al*[2], who observed 0.07–0.17 sec in infants and 0.11 sec at the age of 12–14 year of age. Sharieff *et al*[3] observed, 0.08–0.15 sec in infants and 0.12–0.20 sec in adolescence (12–15 years). However in new born the upper limit (98th percentile) value of our study was higher than the study of Park *et al*[6] where the mean value of the PR interval in new born ranges from 0.075–0.11 sec (0.10 sec). Rijnbeek *et al*[5] observed 0.077–0.12 sec (0.099 sec) in infants and 0.10–0.16 sec in adolescence. Although their study supports our study by means of correlation between PR interval and heart rate with age that the PR interval was progressively and significantly increased with age up to 4 year of age. (Figure-2)

The mean value of QRS duration in new born were found 54 ms (37–80 ms) in new born and 75 ms at the age of 6–14 years. The normal limits for the QRS duration are substantially higher than those reported by Davignon *et al*[2]. For instance, 51 ms (18–75 ms) in infants and 65 ms in children aged 12–16 years but lower than the study of Rijnbeek *et al*[5] who observed 50–85 ms in infants and 90 ms in adolescence. MacFarlane *et al*[7] observed a median QRS duration of 86 ms at the age of 13–14 years. May be because in our study QRS duration was calculated only in V5 lead similar to Davignon *et al*[2], but in our study the mean value 75 ms represents the 6–14 age group as compared to 65 ms in the Davignon study representing 12–16 years age group. Whereas Rijnbeek *et al*[5], and Mac Farlane *et al*[8], determine the QRS duration over all leads, which yields longer QRS durations.

In our study, the mean value of Q-T interval (QTc) in new born ranges from 317–432 ms (375 ms) and 303–410 ms in infants while in adolescence 361–523 ms (410 ms). So, the mean value of QT interval was not significantly changed with age compared to heart rate. We found an upper limit of normal QTc interval approximately 523 ms, which is higher than the commonly used criterion of 440 ms described by Park *et al*.[6] Although, the higher value of the QTc was also reported by Rijnbeek *et al*[5] (450 ms), Venkatesh *et al*[4] (490 ms) and Richard *et al*[8] (490 ms).

This discrepancy in the evaluation of the QTc interval in infants and children should be noted, particularly when relying on computer analysis of ECG intervals. In our study higher value of QTc interval 523 ms may be due to physiological prolongation of QTc in hot, dry and sweaty climate of rural Rajasthan.

In diagnosing ventricular hypertrophy, amplitude criteria for different ECG parameters are employed. Deep Q waves in V6 are suggestive of left ventricular hypertrophy.[9] The upper limit of normal of the Q-wave amplitude in our study was almost similar to Davignon *et al*[2] in all age groups. For example we found Q wave amplitude (amp) in infants (1–3 month of age) 0.15 mV (0.4 mV) which is almost similar to Devignon who reported 0.12 mV (0.55). We found an upper limit of normal Q-wave amplitude 0.7 mV (0.30 mV) in lead III, 0.07 mV (0.24 mV) in lead V6 which is similar to Davignon observation 0·04 mV (0.3 mV) in lead III and 0.04 mV (0.28) mV in lead V6, while our observations were substantially lower than reported by Rijnbeek, *et al*[5]. For example, in infants (1–3 month of age) 0.29 mV (0.50 mV) and for children aged 12–14 years the upper limit of normal of the Q-wave amplitude is 0.10 mV (0.29 mV) in lead III and 0.11 mV (0.43 mV) in lead V6. Macfarlane *et al*[7], also obtained higher results for Q-wave amplitudes in neonates.

Considering that narrow deep Q waves contain relatively high frequencies, in contrast to our findings may demonstrate the effect of using a higher sampling rate by Rijnbeek *et al*.[5] Another reason that may partly explain the differences is that they may be only included non-zero values in computing the percentiles. We included zero values in computing the percentiles. This was also done by Davignon *et al.*[2] When we recomputed the upper limit of normal of the Q-wave amplitude with zero values included, the upper limit of normal decreased to 0.47 mV.

R- and S-wave amplitudes in the precordial leads are important parameters in the diagnosis of both right and left ventricular hypertrophy.

We found considerable differences in R- and S-wave amplitudes compared to Rijnbeek *et al*[5], but quite similar to Davignon *et al*[2], especially in V6. For example, in our study the mean value of the R-wave amplitude in V6 for children aged 8–12 years is 1.2 mV as compared to Rijnbeek *et al*[5] who reported 2.09 mV while 1.68 was reported by Davignon*et al*[2]. Higher R-wave amplitudes in V6 were also presented by Macfarlane *et al*, who found a mean R-wave amplitude in V6 of 1.9 mV for children aged 5–12 years.

For all age groups, the upper limits of normal of the R-wave amplitude in V6 are substantially lower in our study, e.g., 1.7 mV for children aged 5–8 years compared to Rijnbeek *et al*[5], is 3.14 mV and 2·65 mV in the study of Davignon*et al*[2]. Notably, the upper limit of normal of the R-wave amplitude in V3, V2 and especially V4 is lower in almost all age groups. For instance, Davignon *et al*[2] report an upper limit of normal of 4.5 mV in V4 for children aged 3–5 years, and 3.27 mV reported by Rijnbeek *et al*[5] are quite higher as compared to 2.9 mV in our study. R-wave amplitudes in V4 larger than 3.5 mV are exceptional in our material.

S-wave amplitudes are considerably lower than the reported by Rijnbeek *et al*[5] and quite similar as compared to Davignon *et al*[2] in V6 for all age groups, and in V4 after 3 years of age. In the other precordial leads the S-wave amplitude is comparable in most age groups. These findings suggest that the amplitude criteria for ventricular hypertrophy should be adjusted.

Influence of sex differences on the paediatrics ECG has been reported in a number of studies.[10-13] However, to our knowledge this is the first study that examined sex differences in amplitude measurements for children in all age groups in western Rajasthan. In our study, amplitudes of the Q, R, and S waves are higher for boys than for girls especially during adolescence. For example, the upper limit of normal of the R wave in V1 is 0.65 mV for boys and 0.51 mV for girls in the age group of 12 to 16 years. Little change in voltages is seen in boys during adolescence, while in girls a progressive decline is observed. In a study of 114 adolescents, Strong *et al* stated that the sex differences were primarily a reflection of the boys being bigger in size than girls of reproductive age. Another reason for the amplitude differences during adolescence could be the development of breast tissue. Moreover, we found clinically significant differences at younger ages, especially in the S waves in the left precordial leads. At this point we are none the wiser about the sex differences at these young ages.

Overall, the amplitude differences are substantial and indicate that sex-dependent criteria could improve the sensitivity and specificity for left ventricular hypertrophy in children. For adolescents, this was already noted by Walker *et al*[12], in the early 1970s but to our knowledge it is not used in daily practice.

Furthermore, effects of gender on ECG interval measurements were seen for QRS duration, which is consistently longer for boys in all age groups. This was also previously shown by Rijnbeek *et al*[5] and Macfarlane *et al*[7]. No substantial sex differences for the QTc interval could be demonstrated.

However, in the group aged 12–16 years, the upper limit of normal of the QTc interval (500 ms for boys and 523 ms for girls) only marginally overlapped, possibly indicating longer QTc intervals for girls. The difference appears to be due to QT shortening in boys rather than QT prolongation in girls.[13]

REFERENCES

1. O'Connor M, McDaniel N, Brady WJ. The pediatric electrocardiogram. Part I: Age-related interpretation. Am J Emerg Med 2008;26(2):221–8.
2. Davignon A, Rautaharju P, Boisselle E, Soumis F, Mégélas M, Choquette A. Normal ECG standards for infants and children. PediatrCardiol 1980;1(2):123–31.
3. Sharieff GQ, Rao SO. The pediatric ECG. Emerg Med Clin North Am 2006;24(1):195–208.
4. Venkatesh S, Prabhu S. Pediatric Electrocardiogram The Basics. Pediatric On call [serial online] 2007 [cited 2007 March 1];4. Art #9. Available from: http://www.pediatriconcall.com/fordoctor/diseasesandcondition/pediatric_cardiology/steps_to_read_ecg2.asp
5. Rijnbeek PR, Witsenburg M, Schrama E, Hess J, Kors JA. New normal limits for the paediatric electrocardiogram. Eur Heart J 2001;22:702–11.
6. Park MK, Guntheroth WG: How to read pediatric ECG, 3rd ed. St. Louis, Mosby, 1992.
7. Macfarlane PW, McLaughlin SC, Devine B, Yang TF. Effects of age, sex, and race on ECG interval measurements. J Electrocardiol 1994;27(supplt):14–9.
8. Harrigan RA, Jones K. ABC of clinical electrocardiography: Conditions affecting the right side of the heart. BMJ 2002;324(7347):1201–4.
9. Liebman J, Plonsey R, Gillette P. Pediatric cardiology. Baltimore: Williams &Wilkins;1982.
10. Strong WB, Downs TD, Liebman J, Liebowitz R. The normal adolescent electrocardiogram. Am Heart J 1972;83:115–28.
11. Pearl W. Effect of gender, age and heart rate on QT interval. Pediatr Cardiol 1996;17(3):135–6.
12. Walker CHM, Rose RL. Importance of age, sex and body habitus in the diagnosis of left ventricular hypertrophy from the precordial electrocardiogram in childhood and adolescence. Pediatrics 1961;28:705–11.
13. Rautaharju PM, Zhou SH, Wong S, Calhoun HP, Berenson GS, Prineas R, *et al*. Sex differences in the evolution of the electrocardiographic QT interval with age. Can J Cardiol 1992;8(7):690–5.

Address for Correspondence

Dr. Raghuveer Choudhary, Room No. 126, Department of Physiology, Dr. S. N. Medical College, Jodhpur-342001, India. **Cell:** +91-982-9216643

Email: drraghu74@yahoo.com