Reproducibility of QT Parameters Derived from 24-hour Ambulatory ECG Recordings in Healthy Subjects

Hanne Arildsen, M.D., Evald Høj Christiansen, M.D., Ph.D.,
Anders Kirstein Pedersen, M.D., D.M.Sc.,
and Henning Mølgaard, M.D., D.M.Sc.

From the Department of Cardiology, Skejby University Hospital, Aarhus, Denmark

Aim: To estimate the reproducibility of QT parameters derived from 24-hour ambulatory ECG recordings.

Method: Ten healthy volunteers aged 25 to 41 years participated. In two 24-hour ambulatory ECG recordings obtained 1 day apart, the QT interval was measured manually at stable heart rates in approximately 16 periods during daytime and 6 periods during nighttime. The association between the QT and RR interval was described by linear regression for day and nighttime separately and the following QT parameters were calculated: the QT interval at heart rate 60 beats/min during daytime (QT(60)day), slope(day), slope(night), and the difference in QT(60) between day and nighttime (Δ QT(60)). The QT parameters were assessed four times for each participant to discriminate method inaccuracy from day to day variation. The reproducibility was estimated as the coefficient of repeatability, the relative error, and the ratio between within-subject variability and between-subject variability.

Results: The coefficient of repeatability, the relative error and the ratio, respectively, were 19 ms, 1.8% and 0.5 for QT(60)day, 0.076, 21% and 0.68 for slope(day), 0.116, 43% and 1.37 for slope(night), and 37 ms, 325% and 1.19 for Δ QT(60) when estimating the overall day to day reproducibility. Inaccuracy of QT measurement accounted for approximately 40% of this variation, whereas the error caused by selecting segments was small.

Conclusion: QT(60)day has a high reproducibility and may with advantage replace the conventional QT interval measured on a resting ECG. To assess QT dynamics, the slope of the regression line during daytime is suitable and the short term reproducibility acceptable for clinical trials. Regarding slope(night) and Δ QT(60), the variation is high and the parameters should be used with caution.

A.N.E. 2001;6(1):24-31

reproducibility; QT interval; QT dynamics; ambulatory ECG recording

The QT interval on the surface electrocardiogram (ECG) is an indirect measure of myocardial depolarization and repolarization. A prolongation of the QT interval in a 12-lead resting ECG has been associated with an increased risk of cardiovascular death in both healthy subjects^{1,2} and patients with heart disease.³ The QT interval, however, is not a static figure but is modulated by several factors

including heart rate and autonomic nervous system activity.^{4,5} Using 24-hour ambulatory ECG recordings, alterations in the relationship between the QT and RR interval has been demonstrated in diabetic patients with autonomic neuropathy,⁶ in patients with idiopathic ventricular tachycardia despite a normal resting QT interval,^{7,8} and in patients with long QT syndrome, where differences in rate-

This study was supported by the Institute of Experimental Clinical Research, University of Aarhus, Denmark.

Address for reprints: Dr. Hanne Arildsen, Department of Cardiology (Research unit), Skejby University Hospital, DK-8200 Aarhus N, Denmark. Fax: +45 89496009; E-mail: arildsen@dadlnet.dk

dependence of the QT interval have proven to increase the diagnostic performance.⁹ A dynamic approach relating the QT interval to heart rate under different conditions may therefore add valuable information concerning repolarization abnormalities.

Several software programs have been developed for automatic measurement of the QT interval on ambulatory ECG recordings⁸⁻¹¹ and the methods have been evaluated against "the gold standard"—manual measurements. Regardless of automatic or manual measurement, the day-to-day reproducibility of the dynamic QT parameters has been poorly investigated. Knowledge about the natural variability of a parameter is essential for the evaluation of changes over time or alterations due to interventions and differences in reproducibility may influence the choice of QT parameter for the investigation in mind.

The aim of this study was (1) to describe the association between the QT and RR interval on 24-hour ambulatory ECG recordings, (2) to determine the reproducibility of QT parameters derived from 24-hour ECG recordings in healthy subjects, and (3) to evaluate possible sources of poor reproducibility.

MATERIAL AND METHODS

Participants

Ten healthy subjects were drawn from a group of 14 control persons (friends, colleagues) participating in a study of heart rate variability in diabetes.¹² The subjects were selected according to ambulatory ECG recordings of good quality with well-defined T waves.

Ambulatory ECG

During daily activities two 24-hour ambulatory ECG recordings were carried out 1 day apart using a Tracker two-channel tape recorder (Reynolds Medical, United Kingdom). The time of going to bed and arising from bed were registered in a diary. Replay and R-R interval measurements were performed by Reynolds Pathfinder 700 system (Reynolds Medical) using a sampling frequency of 128 Hz. Each 24-hour recording was divided into day and nighttime. Nighttime was defined according to the diary from time of going to bed plus 20 minutes until time of arising from bed minus 20 minutes. This corresponded to the heart rate trend

curve (heart rate/min) so that the transition zones, when going from awake to sleep and from sleep to awake, were included in daytime.

From the heart rate trend curve, periods of stable heart rate for at least 3 minutes were selected. Within each period, an ECG segment was chosen where the instantaneous heart rate was within the range of ± 3 beats/min of the mean heart rate for the last minute. The segments were printed out at a paper speed of 25 mm/s, and the QT interval was measured in lead CM5 from the beginning of the QRS complex to the end of the T wave, defined as the intersection between a tangent to the steepest portion of the downsloping T wave and the P-R baseline. All measurements were made manually by one observer (H.A.) using a random zero digital slide gauge. For each segment, an average value of the QT interval and the preceding R-R interval, respectively, were calculated from five consecutive complexes to cover the variations in the R-R interval caused by breathing.

For each 24-hour recording, the QT and R-R interval were measured in approximately 16 segments during daytime and 6 segments during nighttime. For both time intervals, the selected ECG segments were evenly distributed within the widest possible R-R range. The association between the QT and R-R interval was described for day and nighttime separately by linear regression.

Using the equation of the regression line the following parameters were calculated:

Slope: the coefficient of regression

QT(60): the QT interval at heart rate 60 beats/min

Δ QT(60): the difference in the length of the QT interval between day and nighttime at heart rate 60 beats/min

To assess the reproducibility of the different parameters, the day and night regression lines were estimated four times for each participant:

Examination A: Day 1. First examination.

Examination B: Day 1. Second examination based on repeated measurements of the segments selected in A (a second printout). The difference in the parameters between A and B expresses the inaccuracy of the manual measurement of the QT interval.

Examination C: Day 1. New segments were selected from the 24-hour ECG recording without any knowledge of the segments chosen in examination A. The difference between A and C sums up

measurement inaccuracy and error induced by selecting segments.

Examination D: Day 2. The difference between A and D estimates the overall day to day reproducibility of the different QT parameters and includes both method inaccuracies and the biological short term variation.

Statistics

Data are presented as mean and standard deviation (SD) or range. The association between the QT and R-R interval on 24-hour ECG recordings was expressed by Pearson's coefficient of correlation and the relation between the day-to-day difference in slope and R-R range/number of measured segments by Spearman's coefficient of correlation. A paired *t*-test, or Wilcoxon signed rank test when appropriate, was used to compare the coefficient of correlation, slope, QT(60), R-R range, and number of measured segments for day and nighttime, respectively. For the repeated measurements reproducibility was estimated in three different ways:

- (1) Bias (mean difference) and coefficient of repeatability. Coefficient of repeatability equals 2 times the SD of the differences and is the value below which 95% of the differences are expected to fall.¹³ A paired *t*-test was used to test the bias against the null hypothesis.
- (2) Relative error. Relative error was calculated as the absolute difference between two measurements in percentage of their absolute averaged value. When comparing the relative error of the different QT parameters, Wilcoxon signed rank test was used.
- (3) Within-subject variability compared to between-subject variability. The ratio was expressed for each QT parameter as the mean absolute difference between two measurements divided by the SD of all 40 measurements. The smaller the ratio the better the test distinguishes between subjects, whereas a high ratio indicates a low reproducibility.^{14,15} For all comparisons a P value < 0.05 was considered statistically significant.

RESULTS

The participants (6 males and 4 females) had a mean age of 32 years (range 25 to 41 years). All

declared themselves healthy, no one used cardio-active medication, and no one presented with abnormalities on the resting ECG.

Ambulatory ECG

For all participants we found a linear correlation between the QT and RR interval measured on 24-hour ambulatory ECG recordings (Fig. 1. Examination A shown). The association was significant ($P < 0.05$) during daytime in all examinations and during nighttime in 36 of 40 examinations, whereas the coefficient of correlation was highest during nighttime (mean $r \pm SD$) (0.83 ± 0.12 vs 0.90 ± 0.11 (all nighttime readings); $P = 0.004$). The R-R range was 338 ± 122 ms and 219 ± 78 ms for day and nighttime, respectively ($P < 0.0001$), and the number of measured segments at daytime was (mean [range]) 16 (13–19) and at nighttime 6 (4–8) ($P < 0.0001$). A significant prolongation of QT(60) was found during nighttime (11 ± 13 ms; $P < 0.0001$), but data revealed no significant difference between slope(day) and slope(night) ($P = 0.7$).

Day and night slope, QT(60)day and Δ QT(60) are shown in Table 1. The between-subject variability (SD of all 40 examinations) was for slope(day) 0.043, for slope(night) 0.040, for QT(60)day 14 ms, and for Δ QT(60) 13 ms.

Reproducibility

Comparing examination A with examination B, C, and D, respectively, the absolute difference, the relative error, bias, coefficient of repeatability, and the within-subject/between-subject variability were calculated for each of the four QT parameters (Table 1).

For all three comparisons, QT(60)day had the lowest relative error (highest reproducibility) compared to slope(day), slope(night), and Δ QT(60) ($P < 0.01$). Considering the day-to-day reproducibility (examination A vs examination D), slope(day) had a lower relative error than slope(night) and Δ QT(60) ($P < 0.05$).

The ratio between the within-subject variability and between-subject variability as well showed a poor reproducibility for Δ QT(60) and slope(night) as both parameters had a ratio above one. This means that the physiological variation exceeds the variability between the participating persons making it difficult for the parameters to differentiate between possible risk groups.

In Figure 2, four separate Bland-Altman plots illustrate the day-to-day difference against mean

Figure 1. The linear correlation between the QT and RR interval at daytime (open circles, dashed regressions lines) and nighttime (filled circles, solid regressions lines) during 24-hour ambulatory ECG recordings. Day 1 (examination A) shown for each of the 10 participants.

Table 1. Reproducibility of Day and Night Slope, QT(60) and Δ QT(60)

	Mean (SD)		Absolute Difference Mean (SD)	Relative Error Mean (SD), %	Within-Subject Variability/ Between-Subject Variability	Bias	Coefficient of Repeatability
Slope (day)							
A	0.136 (0.047)						
B	0.140 (0.050)	A vs B	0.012 (0.012)	9.1 (8.8)	0.29	-0.003	0.034
C	0.136 (0.040)	A vs C	0.013 (0.009)	9.8 (5.4)	0.31	0.0002	0.034
D	0.148 (0.041)	A vs D	0.029 (0.025)	21 (16)	0.68	-0.012	0.076
Slope (night)							
A	0.152 (0.041)						
B	0.158 (0.037)	A vs B	0.019 (0.013)	13 (9.5)	0.48	-0.007	0.046
C	0.143 (0.029)	A vs C	0.031 (0.024)	20 (11)	0.78	0.008	0.076
D	0.118 (0.045)	A vs D	0.055 (0.036)	43 (24)	1.37	0.033	0.116
QT(60)day							
	ms		ms			ms	ms
A	387 (15)						
B	385 (15)	A vs B	2 (3)	0.6 (0.7)	0.17	1.6	6
C	384 (14)	A vs C	3 (4)	0.9 (1.0)	0.25	2.7	9
D	388 (13)	A vs D	7 (6)	1.8 (1.5)	0.50	-0.6	19
ΔQT(60)							
A	14 (14)						
B	12 (14)	A vs B	5 (4)	49 (52)	0.40	1.9	13
C	13 (13)	A vs C	4 (5)	48 (63)	0.32	1.6	12
D	6 (9)	A vs D	15 (13)	325 (468)	1.19	8.4	37

QT(60)day = QT interval at heart rate 60 beats/min calculated from the regression line during daytime; Δ QT(60) = difference in the calculated QT interval at heart rate 60 beats/min between day and night; (A) Day 1 = first examination; (B) Day 1 = second examination based on repeated measurements of the segments selected in A; (C) Day 1 = third examination, where new segments were selected for measurement; (D) Day 2. SD = standard deviation; relative error = absolute difference/absolute mean value of the two measurements; within-subject variability/between-subject variability = mean absolute difference/SD of all 40 measurements; bias = mean difference; coefficient of repeatability = $2 \times$ SD of the differences.

for QT(60)day, Δ QT(60), and the slopes, respectively. Δ QT(60) and slope(night) had the largest bias but no systematic error was found (bias vs zero; $P \geq 0.1$ for all four parameters). The coefficient of repeatability, too, was highest for Δ QT(60) and slope(night). Compared to QT(60)day, where a significant change only required 19 ms (coefficient of repeatability (Table 1)), Δ QT(60) had to vary at least 37 ms from one day to the other before a difference was significant. This may be compared to mean values of QT(60)day and Δ QT(60) of 386 ms and 11 ms, respectively. Likewise, the reproducibility of slope(night) was considerably less than the reproducibility of slope(day) as a day-to-day difference in slope(night) had to be 50% higher than for slope(day) before being significantly different.

Applied to all QT parameters, inaccuracy of manual QT measurement accounted for approximately 40% of the day-to-day variability and for slope(day), QT(60)day and Δ QT(60) the error caused by selecting segments was small (Table 1). The change in the coefficient of repeatability for

slope(night) from 0.046 to 0.076 due to a new selection of segments was primarily caused by one outlier, for which we could not find any technical error.

DISCUSSION

As the length of the QT interval in the resting ECG has been used for decades in the evaluation of cardiac repolarisation abnormalities, the dynamic change in the QT interval under different conditions recently emerged as an important clinical tool. In the long QT syndrome (LQTS), the diagnostic performance has been improved by measuring the adaptation of the QT interval to an increase in heart rate during nighttime.⁹ Additionally, different dynamic behavior of the QT interval has been identified for different gene mutations. For instance, in patients with LQT3 (LQTS linked to chromosome 3), increased heart rate produces a considerably shortening of the QT interval, whereas only minor changes are seen in the length of the QT interval in LQT2 patients (LQTS linked

Figure 2. Bland-Altman plots for the difference in slope(day), slope(night), QT(60)day, and Δ QT(60), respectively, between day 1 (examination A) and day 2 (examination D). Bias: mean difference (solid lines). 2 SD: Coefficient of repeatability (dashed lines). The figures show a higher reproducibility for QT(60)day and slope(day) than for Δ QT(60) and slope(night).

to chromosome 7).¹⁶ Using a dynamic approach, it therefore seems possible to add valuable information to the established measurement of the QT interval in the resting ECG.

However, before incorporating a new method into general use, it is important to know the reproducibility of the measurements. In this study we evaluated four QT parameters derived from 24-hour ambulatory ECG recordings.

QT(60)day

The calculated length of the QT interval at 60 beats/min during daytime clearly had the highest reproducibility with a day-to-day relative error of only 1.8%. For the QT interval measured on a resting ECG, the day-to-day relative error was estimated by Kautzner et al. to 2.4%–4.6% in healthy subjects.¹⁷ In patients with previous myocardial infarction, Glancy et al. found a relative error and a coefficient of repeatability of 1.4% and 16 ms, respectively, when the same ECG was measured twice by the same observer.¹⁸ The corresponding

figures for QT(60)day in our study was 0.9% and 9 ms. When we expressed the reproducibility of QT(60)day by the ratio between within-subject variability and between-subject variability, we found that the within-subject day-to-day variability was about half the variation in the total group (ratio = 0.5). The calculation was based on a between-subject variability of 14 ms measured in 10 subjects only. In other studies measuring QT(60) in 24-hour ECG recordings, the between-subject variability has been estimated to be 17–26 ms in normal subjects.^{19–21} Thus, using a between-subject variability in the level published elsewhere would only reduce the ratio, making QT(60)day even better to distinguish between subjects.

The improved reproducibility of QT(60)day compared to QT measurements in the resting ECG may be essential when small changes in the QT interval could be of clinical importance, e.g., during drug testing. Furthermore, using the individual regression line to estimate the length of the QT interval at a heart rate of 60 beats/min, formulas often used to

correct the QT interval for heart rate can be avoided. It is a well-known problem that no formula has yet proven optimal at all heart rates, least of all the most frequently used Bazett's formula.²²

Slope

The slope of the regression line between the QT and R-R interval has been used in several investigations to describe the dynamic behavior of the QT interval.^{5,7,8,20,23-25} We found mean values and standard deviations of slope(day) and slope(night) similar to other studies,^{9,19-21} but our data showed a great difference in the within-subject variability of the two parameters, as slope(day) proved to have a significantly higher reproducibility than slope(night). This difference could not be explained by a poor correlation between the QT and R-R interval at night, as this time period had the highest mean coefficient of correlation (0.83 and 0.90 for day and nighttime, respectively; $P = 0.004$). One reason could be the difference in R-R range between day and nighttime (338 ms vs 219 ms; $P < 0.0001$). Although efforts were made to cover the widest possible R-R range, the small changes in heart rate during nighttime made it impossible to find stable heart rates at a range comparable to daytime measurements. Relating the day-to-day absolute difference in slope to R-R range (Fig. 3), a trend against reduced reproducibility with low R-R range revealed ($r = -0.45$; $P = 0.052$). Another explanation

could be the lower number of selected segments during nighttime compared to daytime (in average 6 and 16 segments, respectively; $P < 0.0001$). Relating the difference in slope to number of segments again a trend was seen against a higher difference with a lower number of segments ($r = -0.40$; $P = 0.08$). Thus, both physiological and methodological factors may account for the observed difference in reproducibility between slope(day) and slope(night).

$\Delta QT(60)$

$\Delta QT(60)$ had the poorest reproducibility with a coefficient of repeatability of 37 ms, meaning that two values measured one day apart in the same person may deviate up to 37 ms before a reliable change is present. This should be compared to a mean value of $\Delta QT(60)$ not higher than 11 ms. The parameter also had a very low ability to distinguish between subjects illustrated by a ratio between within-subject variability and between-subject variability higher than one. The mean value of $\Delta QT(60)$ found in this study was comparable with values published elsewhere^{5,11,19,26,27} and our measurement error only accounts for approximately one third of the variation. The major contributor to the low reproducibility was a high day-to-day variability. Despite this, the parameter has demonstrated clinical value in a few studies,^{5,26} and we, too, found a significant difference in the length of

Figure 3. The correlation between the day-to-day difference in slope (examination A vs D) and RR range (I)/number of measured segments(II) in examination A. The figures show a trend against increasing day-to-day difference in slope with decreasing R-R range (I) and decreasing number of measured segments (II).

the QT interval at 60 beats/min between day and nighttime. The result of the reproducibility study shows, however, that the parameter should be used with caution.

Limitations

The results of this investigation are limited to normal subjects with good quality ECG recordings. In patients, the reproducibility of the QT parameters may differ with the disease in question and good quality ECG recordings, depending on the Holter system, patient cooperation, and body figure, are not always obtainable. Furthermore, only 10 persons participated. The measured QT parameters and their variation, however, were comparable to values found by others, and we believe that the reproducibility shown here is applicable to larger populations.

CONCLUSION

We have shown that QT(60)day distinguish well between subjects, have a low day-to-day variability, and have a far better reproducibility than the QT interval measured in a resting ECG. To assess QT dynamics, the slope of the regression line during daytime is suitable and the short-term reproducibility acceptable for clinical trials. Slope(night) and Δ QT(60) have a high day-to-day variability and the parameters should be used with caution.

REFERENCES

- Schouten EG, Dekker JM, Meppelink P, et al. QT interval prolongation predicts cardiovascular mortality in an apparently healthy population. *Circulation* 1991;84:1516-1523.
- de Bruyne MC, Hoes AW, Kors JA, et al. Prolonged QT interval predicts cardiac and all-cause mortality in the elderly. The Rotterdam Study. *Eur Heart J* 1999;20:278-284.
- Algra A, Tijssen JG, Roelandt JR, et al. QTc prolongation measured by standard 12-lead electrocardiography is an independent risk factor for sudden death due to cardiac arrest. *Circulation* 1991;83:1888-1894.
- Ahnve S, Vallin H. Influence of heart rate and inhibition of autonomic tone on the QT interval. *Circulation* 1982;65:435-439.
- Murakawa Y, Inoue H, Nozaki A, et al. Role of sympatho-vagal interaction in diurnal variation of QT interval. *Am J Cardiol* 1992;69:339-343.
- Shimono M, Fujiki A, Asahi T, et al. Alterations in QT-RR relationship in diabetic patients with autonomic dysfunction. *Ann Noninvas Electrocardiol* 1999;4:176-183.
- Fei L, Statters DJ, Gill JS, et al. Alteration of the QT/RR relationship in patients with idiopathic ventricular tachycardia. *PACE* 1994;17:199-206.
- Tavernier R, Jordaens L, Haerynck F, et al. Changes in the QT interval and its adaptation to rate, assessed with continuous electrocardiographic recordings in patients with ventricular fibrillation, as compared to normal individuals without arrhythmias. *Eur Heart J* 1997;18:994-999.
- Neyroud N, Maison-Blance P, Denjoy I, et al. Diagnostic performance of QT interval variables from 24-h electrocardiography in the long QT syndrome. *Eur Heart J* 1998;19:158-165.
- Copie X, Alonso C, Laverne T, et al. Reproducibility of QT interval measurements obtained from 24-hour digitized ambulatory three-lead electrocardiograms in patients with acute myocardial infarction and healthy volunteers. *Ann Noninvas Electrocardiol* 1998;3:38-45.
- Molnar J, Rosenthal JE, Weiss JS, et al. QT interval dispersion in healthy subjects and survivors of sudden cardiac death: circadian variation in a twenty-four-hour assessment. *Am J Cardiol* 1997;79:1190-1193.
- Mølgaard H, Christensen PD, Sørensen KE, et al. Association of 24-h cardiac parasympathetic activity and degree of nephropathy in IDDM patients. *Diabetes* 1992;41:812-817.
- Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307-310.
- Lawrence GP, Home PD, Murray A. Repeatability of measurements and sources of variability in tests of cardiovascular autonomic function. *Br Heart J* 1992;68:205-211.
- Malik M, Kulakowski P, Poloniecki J, et al. Frequency versus time domain analysis of signal-averaged electrocardiograms. I. Reproducibility of the results. *J Am Coll Cardiol* 1992;20:127-134.
- Schwartz PJ, Priori SG, Locati EH, et al. Long QT syndrome patients with mutations of the SCN5A and HERG genes have differential responses to Na⁺ channel blockade and to increases in heart rate. Implications for gene-specific therapy. *Circulation* 1995;92:3381-3386.
- Kautzner J, Yi G, Camm AJ, et al. Short- and long-term reproducibility of QT, QTc, and QT dispersion measurement in healthy subjects. *Pacing Clin Electrophysiol* 1994;17:928-937.
- Glancy JM, Weston PJ, Bhullar HK, et al. Reproducibility and automatic measurement of QT dispersion. *Eur Heart J* 1996;17:1035-1039.
- Toivonen L, Helenius K, Viitasalo M. Electrocardiographic repolarization during stress from awakening on alarm call. *J Am Coll Cardiol* 1997;30:774-779.
- Stramba-Badiale M, Locati EH, Martinelli A, et al. Gender and the relationship between ventricular repolarization and cardiac cycle length during 24-h Holter recordings. *Eur Heart J* 1997;18:1000-1006.
- Coumel P, Maison-Blanche P, Catuli D, et al. Different circadian behavior of the apex and the end of the T wave. *J Electrocardiol* 1995;28(Suppl):138-142.
- Molnar J, Weiss J, Zhang F, et al. Evaluation of five QT correction formulas using a software-assisted method of continuous QT measurement from 24-hour Holter recordings. *Am J Cardiol* 1996;78:920-926.
- Cappato R, Alboni P, Pedroni P, et al. Sympathetic and vagal influences on rate-dependent changes of QT interval in healthy subjects. *Am J Cardiol* 1991;68:1188-1193.
- Cappato R, Alboni P, Codeca L, et al. Direct and autonomically mediated effects of oral quinidine on RR/QT relation after an abrupt increase in heart rate. *J Am Coll Cardiol* 1993;22:99-105.
- Anselme F, Maison-Blanche P, Cheruy P, et al. Absence of gender difference in circadian trends of QT interval duration. *Ann Noninvas Electrocardiol* 1996;1:278-286.
- Coumel P, Fayn J, Maison-Blanche P, et al. Clinical relevance of assessing QT dynamicity in Holter recordings. *J Electrocardiol* 1994;27(Suppl.):62-66.
- Viitasalo M, Karjalainen J. QT intervals at heart rates from 50 to 120 beats per minute during 24-hour electrocardiographic recordings in 100 healthy men. Effects of atenolol. *Circulation* 1992;86:1439-1442.