ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Comparative Characteristics of QT Interval Measurements on ECG Performed Manually and by Automated Method in Male Patients at Rest

Vadim A. Dulskiy*, **Anna V. Davydova**, **Viktor V. Madaev**, **Konstantin S. Tolkachev**, **Natalia M. Balabina**, **Galina M. Orlova**, **Natalia M. Kozlova**, **Andrey V. Scherbatykh**, **Andrey A. Bolsheshapov**, **Dmitry A. Shmakov**

Irkutsk State Medical University, Irkutsk, Russia.

***Corresponding Author: Vadim A. Dulskiy**

Abstract

In the medical practice of cardiologists, cases of incorrect measurement and interpretation of QT interval length are very frequent. The consequences make an incorrect diagnosis and inadequate treatment. The aim of this work is to investigate the efficiency of measuring the QT interval length on an ECG in manual mode and automated mode at rest among male patients. The sample included 3925 ECGs performed among males aged over 15 years old. Each measurement of QT, QTc intervals was performed both in manual and automatic modes. The numerical values matched only in 4.3% of cases. Automatic interval measurements exceeded the real values in 83.8% of cases. The prolongation of QTc intervals over 440 ms in the automatic mode was detected in 20.4% of cases. Over diagnosis was noted in 17.4% of cases. As a conclusion, manual adjustment is required in most cases measurements of prolonged QT, QTc intervals measured in automatic mode. Among the prevailing errors in automatic measurement, the most common were connected with T-waves (lack of diagnosis of T-wave displacement, its low amplitude and alternation). These erroneous measurements amounted to 53.3% of all measurements in automatic mode. The uncertain wave Q (R) accounted for 35.0% of all cases. In addition, 8.3% of cases were attributed to an undetected diagnosis of differences between manual and automatic methods.

Keywords: *T wave, Manual ECG diagnostics, Automatic ECG diagnostics, interval lengths QT, QTc.*

Introduction

The subject of research on the features of the QT interval, as well as its length (QTc), remains its relevance today. In medical cardio logical research, great prognostic attention is paid to the clinic of cardiovascular diseases. Prolongation of the Qt interval can be of hereditary (or primary) origin, as well as be caused by secondary factors (lifestyle, etc.). In the case of interval prolongation, the causative factors are myocardial ischemia, cerebrovascular accident, hypokalemia, hypothermia and hypertension.

Factors also include drug abuse and prolonged use of a number of drugs for prevention of fungal diseases, heart rhythm disorders, antipsychotics, as well as a number of antibiotics [1]. Also there is a gender correlation in the length of Qt intervals, as females tend to have this length larger. This is the reason for a higher incidence of congenital tachyarrhythmia recorded in females [2]. QT interval prolongation is a common sign of ventricular arrhythmias [3]. Prolongation of interval by 50 ms leads to an increase in the possibility of total mortality due to cardiovascular diseases by 1.2 times, while mortality is recorded 1.29 times higher than in the control. The death tendencies from cardiac ischemia increases by 1.5 times, and from sudden cardiac death by 1.2 times [1].

According to Nikitin et al [4].In random male population, the QTc duration of ≥420-440 m sec was associated with a 2-3-fold increase in independent risk of death from all causes and with a 4-5-fold increase in risk of cardiovascular death [4].

At the present time there are standards for QTc duration [5]. For the correct interpretation of QTc duration, it is necessary to accurately measure QT interval and correctly calculate the QTc [6].Inadequate measurements and clinical interpretation of changes in the QTc interval can lead to over diagnosis and unjustified therapy in unaffected individuals, as well as to underestimate the state severity of real patients, which can significantly increase risk of developing life-threatening tachyarrhythmias and sudden death [7].

QT duration analysis continues to be a difficult task, which, according to Nikitin and Kuznetsov [8], is connected with the difficulty of QT interval start and end points determination and the difficulty of differentiating the T and U waves. Since the introduction of ECG waves and intervals automated analysis, researchers have not been satisfied with its quality, as there is a frequent divergence between the manual and software measurements in both the smaller and larger direction.

This situation was described as early as 20 years ago: with an automated analysis of 1058 ECGs in adult Japanese, false-negative results frequency was 10.5%, false-positive - 16.5% compared with a doctor's opinion; the frequency of false-positive computer-assisted findings was 18 times higher than that of trained doctors [9]. In an earlier study by Hagan and Alpert [10] overall measurement accuracy and interpretation of software-based ECG programs was about 80%. 35 years later, J.S. Alpert still is persuaded that ECG computer-assisted interpretation is incorrect in about 20% of cases [11].

Research Questions

In the available literature there were no papers studying how much QT and QTc duration differ with automated and manual (reference) methods of ECG analysis, as well as about possible reasons for their incorrect hardware measurement. Considering that RR interval duration is included in QTc calculation formula, it was interesting to compare its duration with the manual and automated ECG analysis methods.

Research Aim

To examine the frequency of coincidences and divergences in RR duration, as well as the measured and corrected QT intervals on the electrocardiogram (ECG) at rest with manual and automated measurement methods, as well as possible reasons for the divergence between the two measurement methods.

Methods

5145 digital ECGs at rest in 12 generally accepted leads were registered in the random male population and analyzed (age range 15 years and older; both suffering from various diseases and healthy ones). ECG registration was performed with patient on the back after the subject's rest with the help of a digital electrocardiograph of the current generation. Automated analysis was performed by the ECG hardware-software complex.

With RR and QT automated analysis, hardware values were taken, and with the manual method, QT and RR intervals were measured using an electronic ruler with sufficient magnification. Measurements were carried out by specialists who have been trained and have acquired the appropriate certificates.

Measurements were carried out in the second standard lead at a recording speed of 25 mm/s. QT was measured in the fourth QRST complex, and RR intervals were measured in the 3 previous QRST complexes [12].

QT duration was measured manually from the beginning of the QRS earliest onset (transition point of PQ (R) segment isoelectric line to the Q (R) wave) to the T wave offset. QT interval was measured from the onset of Q or R wave to the T wave offset. Main difficulty in accurate measurement of QT interval is T wave endpoint being not always clearly detected due to various reasons (e.g. different recording conditions, algorithm efficiency).

In case of U wave or P wave overlapping the end part of T wave a tangent line was drawn along the downward T wave slope till its intersecting with the baseline, and this point was considered as the QT endpoint. [12]. QTc length was calculated according to a formula: QT/ square root of the previous RR interval [13]. Exclusion criteria from the study were cases of registration on ECG: 1) QRS complex expansion of more than 0.11 sec; 2) ventricles` pre-excitation syndromes; 3) atrial flutter and atrial fibrillation; 4) two pacemakers on one record; 5) allorhythmic extra systoles; 6) isoelectric T wave; 7) artifactual ECG.Statistical processing was carried out via the Shapiro-Wilk criterion, descriptive statistics methods, and table of frequencies using STATISTICA (Stat Soft, USA).

Results and Discussion

Out of 5,145 recorded electrocardiograms 1220 were excluded from further analysis. Reasons for the exclusion are presented in Table 1.

Table 1: Reasons for excluding electrocardiograms from further analysis

		n	%
Correct measurement		1164	95.4
Error	False-negative	22	1.8
	False-positive	34	2.8
Total		1220	100

In 4.6% of cases of the QT measurement, hardware-software complex didn't comply the exclusion rules. In 2.8% of cases, the hardware-software complex excluded the electrocardiograms from the analysis, with no need for this, and in 1.8% of cases, on the contrary, complex did not exclude those ECGs that should have been excluded. Thus, further analysis was performed on a 3925 ECG.

Identical results of the RR interval were obtained with automated and manual methods (Table 2). The duration of QT (and, respectively, QTc) measured with manual method was less than that measured with automated method.

Table 2: QT, QTc and RR with automated and manual methods and calculation

	QT		RR		QTc	
	Automated	Manual	Automated	Manual	Automated	Manual
M	394.0	376.10	0.887	0.887	420.99	402.13
σ	32.13	31.44	0.152	0.150	27.61	27.55
Me	390.0	374.48	0.882	0.882	420.13	400.27
Q_{25}	370.0	354.24	0.779	0.779	403.11	384.28
Q_{75}	420.0	395.24	0.984	0.984	437.15	417.54

Absolute coincidence of QT duration with manual and automated methods took place only in 4.3% of ECGs. It is noteworthy that in the overwhelming majority of cases (83.8%), automated method provided greater values than the manual one (Fig. 1).

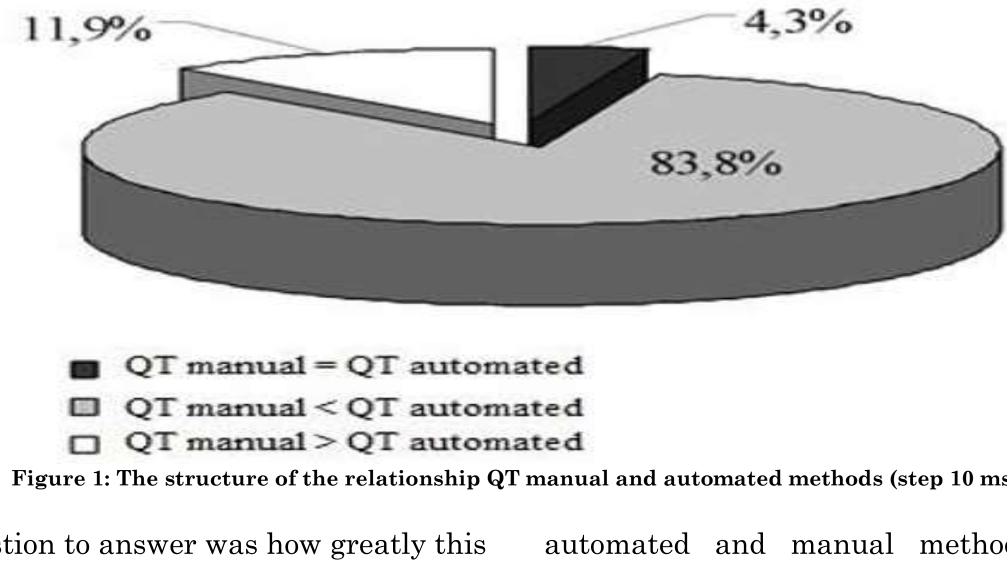

Figure 1: The structure of the relationship QT manual and automated methods (step 10 ms)

Next question to answer was how greatly this overstatement was expressed. To solve this task, all ECGs with overestimated values performed with automated method were divided into groups according to the overestimate (delta) (10 m sec step). First group included ECGSs with 1-10 m sec difference between QT duration after automated and manual methods. In the second group, difference was 11-20 ms, in the third - 21-30 ms, etc. The share of electrocardiograms with QT overestimation (up to 30 ms) amounted to 72.3% with its maximum in range of 11-20 m sec (27.6%) (Fig. 2).

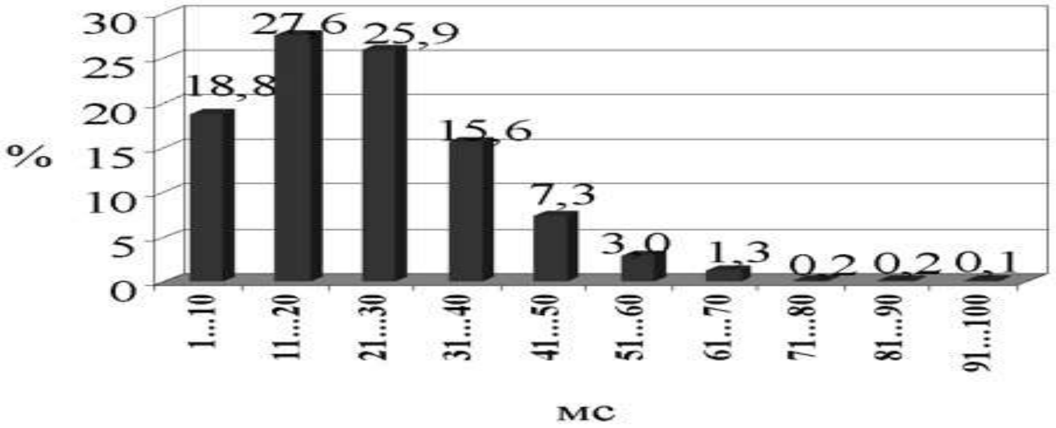

Figure 2: The share of QT overestimates with an automated method, depending on its magnitude (step 10 ms)

In 11.9% of electrocardiograms, automated method showed smaller values than the manual one (Fig. 1). In this case, the underestimation magnitude amounted up to 30 msec in 90% of cases; over 50% of all underestimations were in the range of 1-10 msec (55.6%) (Fig. 3).

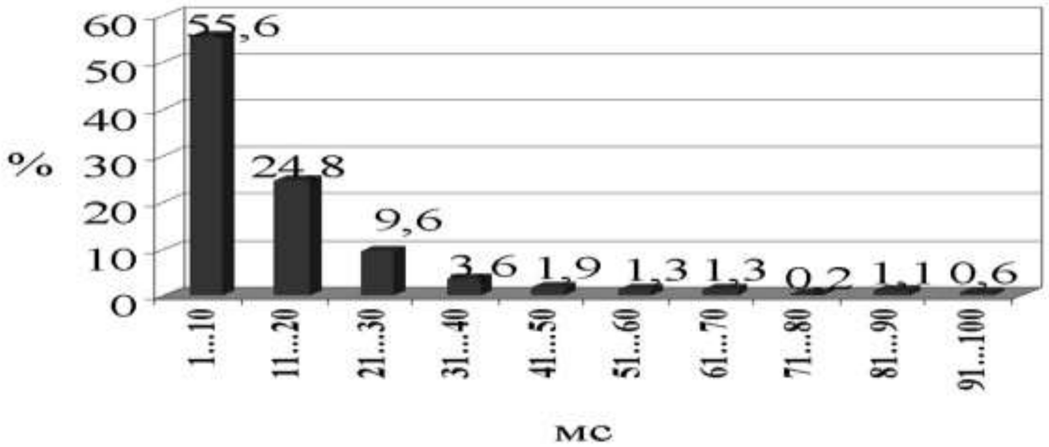

Figure 3: The share of QT underestimation with an automated method, depending on its magnitude (step 10 ms)

QTc duration indicators fully matched only 4.3% of electrocardiograms, similar to the case of QT duration due to manual and automated algorithms. Analysis of the coincidences structure showed similar trend: most automatic measured QT values were greater than the manual ones (83.1%) (Fig. 4.).

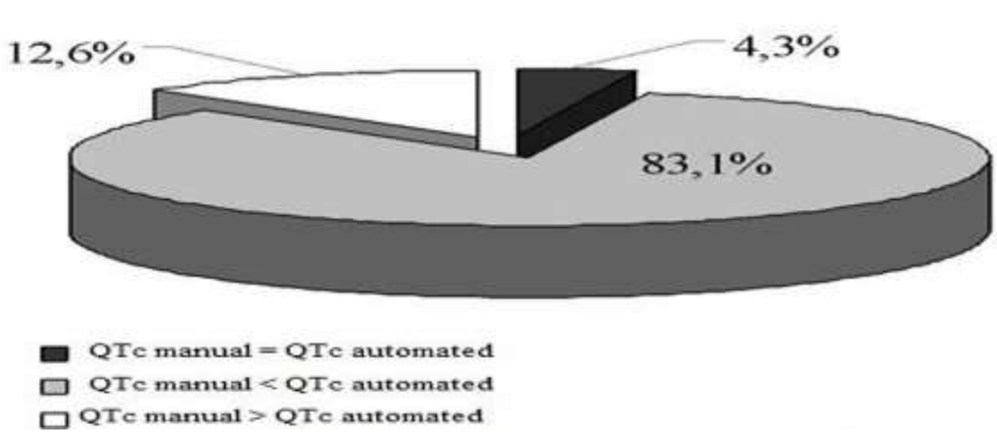

Figure 4: The structure of the coincidence of QTc between the manual and automated methods

Comparison of the QTc values on manual and automated methods showed different data. Thus, share of ECGs with QT overestimate magnitude up to 40 msec was 84.8%. The share of overestimations in the 1-10 m sec and 31-40 msec ranges were almost the same (17.2% and 17.4%). Similar results were for the overestimations in the 11-20 msec and 21-30 msec ranges (26.1% and 24.1%, respectively) (Fig. 5).

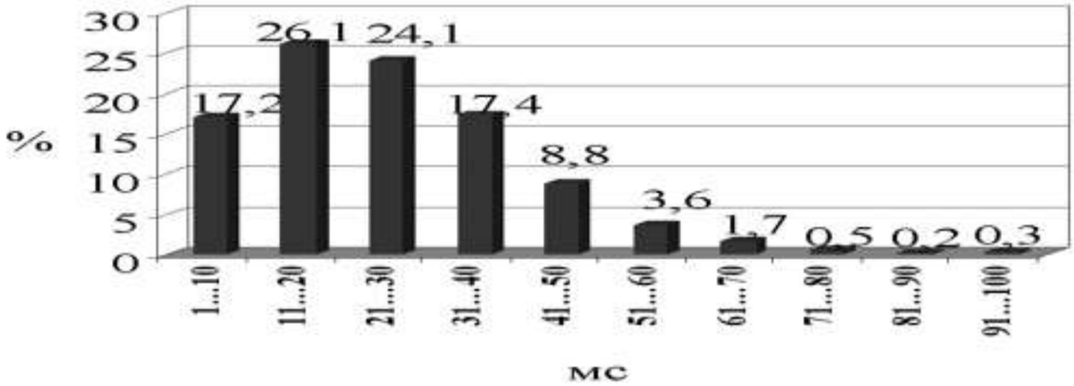

Figure 5: QT overestimate share with automated method depending on its magnitude (step 10 ms).

Structure of QTc underestimation with automated method was almost identical to the structure of QT underestimation. Thus, QTc underestimation share reached 74.8% in the range up to 20 ms, while over 50% of underestimates ranged from 1 to 10 msec (52.2%) (Fig. 6).

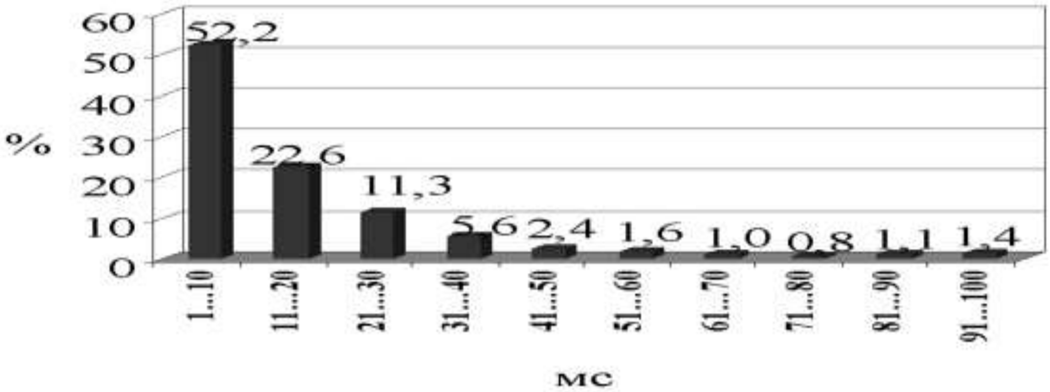

Figure 6: QTc overestimate share with automated method depending on its magnitude (step 10 ms)

From the practitioner's position, it is especially important to monitor the possible QT prolongation over time, both when managing patients with certain pathological conditions and when prescribing drugs that have an effect on the QT duration. In such cases, the physician's main concern is to prevent the interval from lengthening over 440 ms.

In this regard, manual case analysis of the QTc prolongations over 440 msec was performed. According to our data, interval prolongation of over 440 msec was recorded on 294 ECGs. At the same time, automated algorithm recorded QTc prolongation over 440 msec in 234 cases. Automated QTc algorithm didn't register interval prolongation over 440 msec in 60 cases (every fifth case). Therefore, manual and automated registration of QTc prolongation over 440 msec coincided in 79.6% of cases. In 20.4% of the automated algorithm failed to register the existing QTc prolongation.

These ECGs indicating potential risk would be missed without further manual reevaluation. In more than half of cases (58.3%), QTc magnitude underestimation ranged from 1 to 30 msec for automated method (Table 3).

Table 3: Structure of QTs underestimation with automated measurement and calculation in different ranges (step 10 ms)

Underestimate value QTc, msec	Case number	Case share, %	Cumulative frequency, %
1-10	11	18.3	18.3
11-20	11	18.3	36.7
21-30	13	21.7	58.3
31-40	9	15.0	73.3
41-50	3	5.0	78.3
Over 50	13	21.7	100.0

Automated method of measuring and calculating QTc didn`t detect the values over 440 msec in 20.4% of cases. Possible causes of these differences were analyzed and presented in Table 4.

Table 4: Possible reasons for under diagnosis of QTc over 440 msec during automated measurement and calculation

Reasons	Case number	Case share, %	Cumulative frequency, %
Unknown	5	8.3	8.3
T wave alternation	8	13.3	21.7
T wave low amplitude	9	15.0	36.7
Undetected Q (R) onset	21	35.0	71.7
Undetected T wave end	15	25.0	96.7
Undetected Q (R) onset and T wave offset	2	3.3	100.0

The most frequent reason for difference between the manual and automated registration of QTc over 440 msec was the undetected Q (R) wave onset (35%) which means that measurement started at different points. Causes associated with T wave (undetected T wave offset point, low-amplitude T wave, T wave alternation), together resulted in 53.3% of the differences. It is noteworthy that in 8.3% of cases, the cause of different detection of QTc> 440 msec with manual and automated methods was not established.

Cases of QTc interval over diagnosis over 440 msec with automated registration and its normal duration when measured and calculated in a manual way were particularly interesting.

Out of 3925 ECG analyzed, 3640 ECG were detected with QTc duration below 440 msec during a manual analysis. In a subsequent automated analysis of these 3640 ECGs duration was determined to be longer than 440 ms on 632 ECGs. Consequently, in some cases (17.4%), over diagnosis of QTc duration over 440 msec took place with ECG automated analysis.

Software interpretation of ECGs took its start in the 1950s, when conversion of the analog signal into digital form became possible. Since then, automated ECG computer interpretations have become common, even at the primary care stage, thanks to supply portable ECG machines with interpretive algorithms. This has significantly increased the number of ECG registrations, but the computer cannot be held responsible for misinterpretation due to recording errors (muscle artifacts, confusion in leads). In addition, with the pathology present, a computer can make a critical mistake and give an incorrect conclusion. These errors require all computerized conclusions to be reevaluated by trained physicians, who also have an advantage in the clinical context [14]. The reason that the most advanced computer software for ECG interpretation is making mistakes, according to Alpert [11] it's the remarkable ability of the human brain to recognize visual images (patterns). This ability is the reason that a person with minimal prior art knowledge, for example, can recognize a Van Gogh painting without looking at the accompanying label. Van Gogh's distinctive style is easily recognized by the very complex pattern recognition system of our central nervous system. The ability to recognize complex visual patterns in humans has obvious evolutionary causes.

In the world of our primate ancestors, the ability to distinguish potential nutritious prey, while avoiding hungry carnivorous animals, gave a huge advantage in natural selection. A computer that reads an ECG does not have image recognition skills, although in the future this is quite possible. While the ability to recognize images is the greatest asset only of our brain, and therefore, the author concludes, in the foreseeable future, trained medical specialists will have to reevaluate computer-interpreted ECG findings.

The great advantage of the doctor, moreover, is that he knows additional clinical information about a particular patient whose ECG he is analyzing [11]. In our study, in a random population of men older than 15 years, only in 4.3% of cases of QT and QTc duration were identical according to the manual and automated methods. In 83.8% of cases, the automated method overestimated the QT and QTc duration. Potentially dangerous QTc duration of more than 440 msec was not recognized by automated counting in 20.4% of cases, and, on the contrary, in 17.4% of cases, QTc over 440 msec was recognized where QTc was below 440 msec.

QT length is known to have gender characteristics-women tend to have this interval longer [2]. Previously, we analyzed the frequency of differences in QT and QTc duration according to manual and automated algorithms in random female population (age range 15+) and obtained similar results. When comparing QT and QTc duration, their values were completely identical only in 4.1% of cases. In most cases (83.9%), there was an overestimation of QT and QTc intervals with an automated method. The potentially dangerous QTc duration over 450 msec (for women) was not recognized by automated algorithm in 17.0% of case. On the contrary, QTc over 450 msec were recorded in 17.4% of cases with actual QTc duration below 450 msec [15].

Some negative points of QT measurement can be counterbalanced (measurements are usually taken in the second standard lead at a paper speed of 25 mm/s). Others remain problematic to date (e.g. definition of T wave end) [16]. These reasons cause most differences in the duration of QT and, accordingly, in the calculated QTc with manual and automated methods. Study on comparing automated ECGs results analysis using different current-generation electrocardiographs from different manufacturer's revealed insignificant differences in ECGs interpretation in healthy individuals, while individuals with a genetically determined QT prolongation and other cardiac pathology showed very significant differences even in automated measurements [17, 20].

De Pooter et al [21].Compared QRS duration with manual and automated methods: statistically significant differences in measurement results were found even between digital electrocardiographs of different manufacturers, which, according to the authors, could lead to an incorrect selection of candidates for cardiac resynchronization therapy in case of QRS duration being the only selection criterion. The authors recommended estimating the duration of QRS manually in such situations [21]. Southern and Arnsten [22] drew attention to another problem that may appear with the automated ECG decoding: it is ECG software judgment having an effect on ECG interpretation and medical decision making. Earlier studies showed that with the advent of automated ECG analysis, doctors agreed with the program conclusion more often, even in cases where this conclusion was false [23]. This conclusion was confirmed by Tsai et al [24]. In cases when the program gave incorrect ECG interpretations, interpretation accuracy of these ECGs by doctors also decreased [24]. Southern and Arnsten [22] believe that errors in the software ECG interpretation are still common, software should not replace a qualified doctor in making decisions, but should act only as an auxiliary tool in addition to the conclusions of the specialists. QTc prolongation is regarded as a risk marker for dangerous ventricular arrhythmias and sudden death [3]. Therefore, it is important to correctly and reliably measure the QT interval, and, accordingly, to calculate the QTc interval.

There are certain difficulties in QT measurement. According to Kautzner [25], firstly, this is due to the inaccuracy of determining the T wave end; secondly, due to the fact that different leads determine variants of QRS complex beginning and T wave endings differently. As a result, QT duration measurements differ depending on the lead. Thirdly, technical difficulties also affect the QT duration: at higher paper speeds, the QT interval shortens, and at higher paper sensitivity, QT extends. All this may interfere with the accuracy of automated QT measuring, and these errors are more significant for patients with cardiac pathology than in healthy population [25].

Conclusion

As a result of our study, we found that the diagnosis was overestimated and hypertrophied for automatic ECG monitoring in more than 80% of measurement cases. As it follows, the mandatory presence of a specialist doctor is necessary as a recommendation. In particular, an error was recorded in 58.3% of cases of automatic ECG measurement in estimating the magnitude of the magnitude in the range from 1 to 30 ms compared to the manual measurement method. Thus, the manual method of ECG measuring, in particular of the prolonged QT interval, has an advantage over the automatic one, since it reduces the risk of sudden death and aggravation of cardiovascular diseases. Therefore, QT interval prolongation measurements in the manual mode still preserve their relevance.

References

1. Zhang Y, Post W S, Blasco-Colmenares E, Dalal D, Tomaselli G F, Guallar E (2011) Electrocardiographic QT interval and mortality: a meta-analysis. Epidemiology (Cambridge, Mass.), 22(5): 660.
2. Johnson JN, Ackerman MJ (2009) QTc: how long is too long?. British journal of sports medicine, 43(9): 657-662.
3. Moss AJ (1997) The Long QT interval syndrome. American Journal of Cardiology, 79(6): 16-19.
4. Nikitin U P, Kuznetsov A A, Malyutina S K, Simonova G I (2002) Threshold prognostic indices of the duration and variability of the QT and RR intervals in the unorganized male population. Russian Journal of Cardiology, 37(5): 47-53.
5. Makarov LM, Chuprova SN, Kiseleva II (2004) Comparison of methods for measuring the QT interval and their clinical significance. Cardiology, 44(5): 71-73.
6. Makarov LM, Kisileva II, Dolgikh VV (2006) Evaluation of Q-T interval in children and adolescents 0-17 years old. Cardiology, 46(2): 37-41.
7. Garg A, Lehmann MH (2013) Prolonged QT interval diagnosis suppression by a widely used computerized ECG analysis system. Circulation: Arrhythmia and Electrophysiology, 6(1): 76-83.
8. Nikitin U P, Kuznetsov A A (1998) Dispersion of the QT interval. Cardiology, 38(5): 58-61.
9. Sekiguchi K, Kanda T, Osada M, Tsunoda Y, Kodajima N, Fukumura Y, Kobayashi I (1999) Comparative accuracy of automated computer analysis versus physicans in training in the interpretation of electrocardiograms. Journal of medicine, 30(1-2): 75-81.
10. Hagan AD, Alpert JS (1976) Evaluation of computer programs for clinical electrocardiography. In Computer techniques in cardiology (77-96). Marcel Dekker, Inc, New York.
11. Alpert JS (2012) Can you trust a computer to read your electrocardiogram?. The American journal of medicine, 125(6): 525-526.
12. Goldenberg I LAN, Moss AJ, Zareba W (2006) QT interval: how to measure it and what is “normal”. Journal of cardiovascular electrophysiology, 17(3): 333-336.
13. Bazett HC (1920) An analysis of the time relationship of electrocardiograms, Heart, 7: 353-370.
14. Smulyan H (2019) The computerized ECG: friend and foe. The American journal of medicine, 132(2): 153-160.
15. Dulsky VA (2011) Comparison of "manual" and automatic methods of measuring the QT interval on the resting ECG in women. Therapist, 10: 23-27.
16. Postema PG, Wild AAM (2014) The Measurement of the QT Interval. Current Cardiology Reviews, 10: 287-294.
17. McLaughlin NB, Campbell RW, Murray A (1995) Comparison of automatic QT measurement techniques in the normal 12 lead electrocardiogram. Heart, 74(1): 84-89.
18. McLaughlin NB, Campbell RW, Murray A (1996) Accuracy of four automatic QT measurement techniques in cardiac patients and healthy subjects. Heart, 76(5): 422-426.
19. Kligfield P, Badilini F, Rowlandson I, Xue J, Clark E, Devine B, Gregg R (2014) Comparison of automated measurements of electrocardiographic intervals and durations by computer-based algorithms of digital electrocardiographs. American heart journal, 167(2): 150-159.
20. Kligfield P, Badilini F, Denjoy I, Babaeizadeh S, Clark E, De Bie J, Helfenbein E (2018) Comparison of automated interval measurements by widely used algorithms in digital electrocardiographs. American heart journal, 200: 1-10.
21. De Pooter J, El Haddad M, Stroobandt R, De Buyzere M, Timmermans F (2017) Accuracy of computer-calculated and manual QRS duration assessments: clinical implications to select candidates for cardiac resynchronization therapy. International journal of cardiology, 236: 276-282.

22. Southern WN, Arnsten J H (2009) The effect of erroneous computer interpretation of ECGs on resident decision making. Medical Decision Making, 29(3): 372-376.
23. Hillson SD, Connelly DP, Liu Y (1995) The effects of computer-assisted electrocardiographic interpretation on physicians' diagnostic decisions. Medical Decision Making, 15(2): 107-112.
24. Tsai TL, Fridsma DB, Gatti G (2003) Computer decision support as a source of interpretation error: the case of electrocardiograms. Journal of the American Medical Informatics Association, 10(5): 478-483.
25. Kautzner J (2002) QT Interval Measurements. Cardiac Electrophysiology Review, 6(3): 273-277.

