Validation of a smartphone-based electrocardiography in the screening of QT intervals in children

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ABSTRACT

OBJECTIVE: A 12-lead electrocardiography is a critical component for the screening of long QT syndrome; however, besides, an electrocardiograph, trained personnel are also necessary which limits the screening capability of conventional electrocardiographs. The development of smartphone electrocardiography technologies provides a potential alternative platform for electrocardiography screening for selective purposes such as arrhythmias and QT interval abnormalities. The aim of this pilot study was to assess the reliability of a smartphone-based electrocardiography device in the measurement of QT and corrected QT intervals in children.

METHODS: In all participants, 10-s smartphone electrocardiography tracing from AliveCor device and a standard 12-lead electrocardiograph were obtained simultaneously. Two pediatric electrophysiologists performed the measurements of QT and corrected QT intervals in a blinded manner with Bazett's formula. The results were compared statistically.

RESULTS: A total of 285 children (mean age 9.8±4.9 years) who presented to our clinic were included in the study. The mean QT intervals obtained from 12-lead electrocardiographs and AliveCor devices were 343±40 ms and 340±41 ms, respectively. The mean corrected QT intervals obtained from 12-lead electrocardiographs and AliveCor devices were 419±28 ms and 415±33 ms, respectively. There was high correlation between the QT intervals of 12-lead electrocardiographs and AliveCor recordings (Pearson's correlation coefficient: 0.83 [p<0.001]) and significant correlation between the corrected QT intervals of 12-lead electrocardiographs and AliveCor recordings (Pearson's correlation coefficient: 0.57 [p<0.001]).

CONCLUSION: AliveCor recordings can accurately detect QT intervals and can potentially be used for the screening of congenital long QT syndrome in children.

Keywords: AliveCor; children; corrected QT; QT; smartphone; sudden death.

Long QT syndrome is a disorder of myocardial repolarization characterized by an abnormally prolonged QT interval on the electrocardiography and an increased risk of sudden cardiac death [1]. The incidence of congenital long QT syndrome has been estimated between 1 in 2000 and 1 in 2500 in the general population [2, 3]. Long QT syndrome is usually diagnosed after a person has a cardiac event such as syncope or cardiac arrest.

Sometimes, this syndrome is diagnosed following the death of a family member [1]. In some individuals, the diagnosis is made when an electrocardiography shows QT prolongation [4]. Early diagnosis with an electrocardiography is important to prevent sudden cardiac death in asymptomatic patients. Although there is a consensus on early diagnosis of asymptomatic long QT syndrome patients, routine electrocardiography screening in in-

fants is still a matter of concern. Our aim in this study was not to prove the necessity or to assess the specificity and sensitivity of electrocardiography screening for QT analysis in children. There are controversial studies, some stating that QT screening has low power; however, there are other studies which show the utility of electrocardiography screening for that purpose [4-7].

With the advancement in the smartphone technology, independent software experts have developed applications for multiple purposes. One such application called AliveCor works in tandem with a phone case with embedded sensors and provides a single channel lead for accurate rate and rhythm assessment [8]. AliveCor electrocardiography has been shown efficient for discriminating and identifying the mechanism of supraventricular tachycardia and diagnosis of atrial fibrillation compared to traditional 12-lead electrocardiography [9, 10]. In addition, it also showed minimization of outpatient admissions to the emergency room with a resultant cost reduction [11]. So far, there is no comparable study between electrocardiography QT and smartphone electrocardiography QT in pediatric population. In our prospective study, we aimed to compare electrocardiography QT parameters obtained with smartphone application (AliveCor) and evaluate the correlation with traditional 12-lead electrocardiography machine. We performed this study to assess the validation of measurement of corrected QT with AliveCor electrocardiography system.

MATERIALS AND METHODS

A total of 285 pediatric and adolescent patients were prospectively enrolled to the study at Istanbul Medipol University Division of Pediatric Cardiology. Informed consent was obtained from patients or their families and an ethical approval was obtained from Istanbul Medipol University Ethics Committee.

We used AliveCor heart monitor coupled with an iPhone cellular phone and the Kardia application (AliveCor, San Francisco, California, United States of America), which is a single-channel bipolar electrocardiography recorder. The device consists of a smartphone software application and a corresponding lightweight hardware component attached to or in close proximity to the phone. To record the electrocardiography, the patient or user touches the hardware with fingers of both hands. It can also be obtained by placing the smartphone case directly on the patient's chest. Chest recordings were performed because recordings obtained from children's

hands noisier than chest recordings. Cardiac electrical activity from the electrodes is transmitted from the user to the smartphone with Bluetooth wireless technology. The smartphone application converts the signal to a digital electrocardiography tracing on smartphone screen, which can be viewed in real time and stored. All recordings can be obtained at a paper speed of 25 mm/s with a gain of 10 mm/mV, which is the same as a standard electrocardiography leads.

Standard 12-lead electrocardiographs (Mortara ELI-250) and smartphone (AliveCor) electrocardiography tracings were acquired for all patients simultaneously. Smartphone electrocardiography tracings were obtained by placing the smartphone case on chest surface horizontally. The recordings with artifact or electrocardiography with unclear T-wave termination were also excluded from the analysis. Electrocardiography tracings for each patient were compared to a standard electrocardiography. Deidentified electrocardiographs (smartphone electrocardiography tracings) and standard 12-lead electrocardiographs were analyzed by two pediatric electrophysiologists (MK and CA) in a blinded manner. AliveCor obtains bipolar electrocardiography recordings from the single channel; hence, electrocardiography recordings do not represent true precordial electrocardiography. On the other hand, it is difficult to mention that extremity recordings are identical with AliveCor recordings [7]. Since in our study, our aim was to screen QT/ corrected QT through the AliveCor, we needed to compare the recordings with standard bipolar lead I recordings. On each smartphone electrocardiography tracings and 12-lead electrocardiography, randomly selected three QT intervals and their corresponding RR intervals were measured to calculate the average corrected QT using Bazett's formula [12] (Fig. 1).
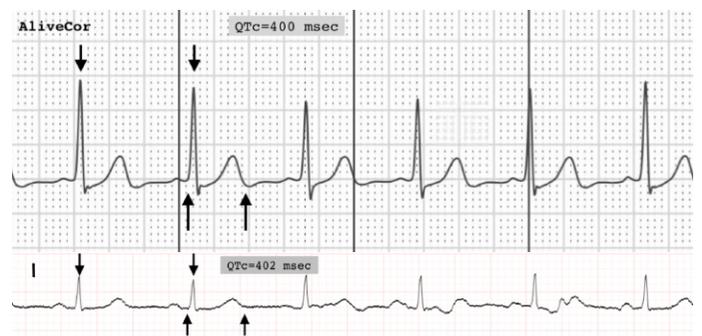

FIGURE 1. The electrocardiography recordings obtained using smartphone electrocardiography and 12-lead electrocardiography from the same patient.

Statistical analysis

Descriptive statistics (frequencies, means, and standard deviations) were calculated. Pearson correlation analysis was conducted to examine the relationship between smartphone electrocardiography tracings QT/corrected QT and standard 12-lead electrocardiography QT/corrected QT. All statistics were obtained using the Statistical Package for the Social Sciences statistics. P<0.05 was considered statistically significant.

RESULTS

In total, 285 patients were enrolled during 4-month study. Of the 285 transmitted tracings, 265 (152 males, 57.6%) were of diagnostic quality. 19 of transmitted tracings (7.3%) were not interpretable due to too much noise or motion artifact and unclear T-wave termination. The ages ranged from 2 months to 20.8 years (mean 9.8±4.9 years). Averaged weight was 39.7±19.0 kg (3 to 92 kilos). 20 patients (7.1%, n=19) had congenital heart disease: Ventricular septal defect (n=4), pulmonary valve stenosis (n=3), transposition of great arteries (n=2), atrial septal defect (n=2), tetralogy of Fallot (n=1), bicuspid aortic valve (n=1), coarctation of aorta (n=1), aortic valve stenosis (n=1), other congenital heart diseases (n=2), and multiple congenital heart disease (n=2). 17 patients had conduction pathology in their 12-lead electrocardiographs: Bundle branch block (n=11), Wolff-Parkinson-White syndrome (n=2), pacemaker (n=2), and long QT syndrome (n=2).

The mean heart rates obtained from 12-lead electrocardiography and smartphone electrocardiography were 92±20 (45–160) BPM and 93±22 (45–165) BPM, respectively. The mean QT interval obtained from 12-lead electrocardiography was 343±40 ms (250–508 ms) and the mean QT interval obtained from smartphone electrocardiography was 340±41 ms (260–520). The mean corrected QT interval obtained from 12-lead electrocardiography was 419±28 ms (333–552 ms) and the mean QTc interval obtained from smartphone electrocardiography was 415±33 ms (250–508). There was a high correlation between the QT intervals of smartphone electrocardiography tracings and 12-lead electrocardiography (Pearson's correlation coefficient: 0.83 [p<0.001]) and reasonable correlation between the corrected QT intervals of smartphone electrocardiography tracings and 12-lead electrocardiographs (Pearson's correlation coefficient: 0.57 [p<0.001]). There was also very high correlation between the heart rate obtained from smart-

Table 1. Average heart rate, QT, corrected QT, and Pearson's correlation using smartphone electrocardiography and 12-lead electrocardiography

Electrocardiography		Pearson's correlation (r)
Mean heart rate (BPM±SD)		
12-lead electrocardiography	92±20	0.92
Smartphone electrocardiography	93±22	
Mean QT interval (ms±SD)		
12-lead electrocardiography	343±40	0.83
Smartphone electrocardiography	340±41	
Mean corrected QT interval (ms±SD)		
12-lead electrocardiography	419±28	0.57
Smartphone electrocardiography	415±33	

SD: Standard deviation.

phone electrocardiography tracings and 12-lead electrocardiographs (Pearson's correlation coefficient: 0.92 [p<0.001]) (Table 1).

DISCUSSION

Long QT is an infrequent and generally asymptomatic disease. However, the first presentation could be sudden cardiac death. Therefore, early diagnosis is important to identify asymptomatic patients and prevent potentially life-threatening symptoms. The use of 12-lead electrocardiography as a universal screening tool is not recommended in the young due to lack of evidence for cost-effectiveness and concerns regarding false-negative diagnoses time and economic consumption, and needs for educated health care workers [13].

In parallel with technical improvements in smartphone technology, new hardware and software were evolved, and consequently, smartphones are used more frequently by the health-care professionals. Effectiveness and reliability of AliveCor electrocardiography, a new smartphone-based Food and Drug Administration - approved electrocardiography tool, has been shown in several studies [9, 11].

The incidence of artifact in our smartphone electrocardiography tracings was 7% and this ratio was found as 4% in a study of Nguyen et al. [11] Although the frequency of artifacts was not high in this study, due to patients with unclear T-wave termination, the rate of over-

all excluded patients was slightly higher. Major reason and explanation for the chest recordings to be noisy were lack of the technicians' initial assessment of electrocardiography. If the AliveCor tracing is repeated in patients with noisy electrocardiography most of them, we can get clean electrocardiographs; however, we did not interrupt our technicians since it was a pilot study, and we were also assessing the feasibility of the ease of applicability of the AliveCor. In our experience, in patients with noisy recordings, we can easily get clean recordings if we repeat the recording. This was our major limitation in the present study.

Although there is no validation study of smartphone electrocardiography in healthy children to assess QT analysis, there are two AliveCor electrocardiography studies of corrected QT validation in adult population. In an observational study of five patients on dofetilide treatment, corrected QT intervals were accurately measured by smartphone electrocardiography [14]. In Haberman et al.'s study, the patients were divided into three groups (healthy young adults, elite athletes, and cardiology clinic patients) and smartphone electrocardiography and standard 12-lead electrocardiography parameters were compared; the correlations of QT and corrected QT were found lower [15]. Nevertheless, the correlation of heart rates in each group was also not higher. This circumstance was explained with the lack of simultaneous recordings. Nevertheless, standard 12-lead electrocardiography recordings were obtained with automatic algorithms and this might affect the results. However, in our study, the correlation coefficient between heart rates obtained with smartphone electrocardiography and 12-lead electrocardiography was 0.92 and this finding verifies simultaneous recording of electrocardiographs. Therefore, these two studies have significant limitations, which make them inadequate as validation studies for QT evaluation in adults.

In the current study, although the correlation between corrected QT measurements was higher compared to other studies, the correlation between QT intervals was not so high (0.57 vs. 0.83). Corrected QT intervals measured with Bazett's formula at variable heart rates have low sensitivity and accuracy; however, QT interval is more reliable [16, 17]. Therefore, even minimal change in heart rate between these two measurement methods will substantially influence corrected QT intervals and discrepancy of our study result could be explained with that.

Conclusion

AliveCor electrocardiography can potentially be used as a practical tool to assess QT intervals in children for screening purposes. Part of the limitations of 12-lead electrocardiography screening can be eliminated with this technology. However, before establishing AliveCor electrocardiography as a practical screening tool for long QT syndrome, larger population of children should be studied along with cost-effectiveness analysis.

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