Further insights into inheritable arrhythmia syndromes: Focus on electrocardiograms
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Accurate electrocardiographic assessment of the QT interval

Teach the tangent

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Chapter 02

ABSTRACT

BACKGROUND
Long QT-Syndrome (LQTS) is a prevalent and possibly lethal disease. Unfortunately, it has recently been shown that the majority of physicians, including many cardiologists, do not recognize a long QT interval when they see one. Conversely, almost 40% of patients referred to specialized centers with a presumed diagnosis of LQTS have a normal QT.

OBJECTIVE
The purpose of this study was to investigate whether we are able to teach inexperienced electrocardiogram (ECG) readers a method that will result in a higher accuracy of QT measurements.

METHODS
Four previously published ECGs (two LQTS, two normal) were assessed by 151 medical students using the following QT measurement method: (1) the end of the T wave is the intersection of a tangent to the steepest slope of the last limb of the T wave and the baseline, in lead II or V5; (2) QTc=QT/√RR; (3) QTc of 450 ms is prolonged. Four months later, 71 students measured the ECGs again. Student results were compared with previously published results on the same ECGs of 25 LQTS experts, 106 arrhythmia experts, and 771 cardiologists and noncardiologists.

RESULTS
Correct QT interval interpretations were achieved by 71% and 77% of students during the first and second test, respectively, as compared with 62% by the arrhythmia experts and <25% by the cardiologists and noncardiologists.

CONCLUSIONS
In this proof-of-principle study, inexperienced ECG readers were able to rather accurately and reproducibly diagnose prolonged and normal QT intervals on four ECGs, as opposed to 877 cardiologists and noncardiologists. If the presented method is used by physicians, a better stratification of their patients’ risk for sudden death due to LQTS (drug induced or congenital) should be possible.
INTRODUCTION

For the past 50 years, assessment of the QT-interval on the ECG has been used to evaluate the risk of a sudden cardiac death due to the Long QT Syndrome (LQTS).\(^1\)\(^3\) Unfortunately, the majority of physicians world-wide, including many cardiologists, do not recognize a long QT when they see one, as recently shown by Viskin et al.\(^4\) Conversely, almost 40% of patients referred to specialized centers with a presumed diagnosis of LQTS have a normal QT.\(^5\) This paradox is dramatic, as LQTS has a prevalence of at least 1 per 2000 persons and is thus sufficiently common to be encountered in the clinical practice of every physician. Furthermore, treatment for LQTS is very effective whereas unrecognized LQTS may have fatal consequences. Importantly, LQTS may be inherited or induced by cardiovascular and non-cardiovascular drugs (e.g. antibiotics, antipsychotics, anesthetics).\(^6\) Without doubt, many patients at risk for sudden cardiac death are not identified, whereas others undergo unnecessarily treatment.

The present study was undertaken to investigate whether we are able to teach inexperienced ECG-readers a standardized method resulting in higher accuracy of QT-measurements. We hypothesized that such a method should focus on defining the end of the T-wave and correcting for heart rate (QTc). An optimal method should furthermore be easy, quick to learn, and give reproducible results. When efficacious, broad implementation would inevitably result in higher recognition of LQTS and thus results in better treatment of these patients. Furthermore, it could also prevent misdiagnosis of patients and subsequent reduce physician induced harm.

METHODS

A proof-of-principle study was initiated with the same methods as used by Viskin et al. to warrant comparability. The Viskin et al. study was assembled around ECG traces of two patients (1 male, 1 female) with congenital LQTS (ECG A+B) and of two healthy females (ECG C+D) (Figure 1). Further patient details were not provided. A gold QT-standard was set for these ECGs by 25 world-renowned LQTS-experts and they have been subsequently interpreted by 106 arrhythmia-experts and 771 cardiologists and non-cardiologists.\(^4\)

As a standardized method for the QT-measurements by the inexperienced ECG-readers, a 3-step approach was used (Figure 2); 1) the end of the T-wave was defined as the intersection of a tangent\(^7\) to the steepest slope of the last limb of the T-wave and the baseline, in lead II or V5; 2) QTc was defined as QT/\(\sqrt{RR}\) from the RR interval between the measured and the preceding complex (Bazett); and 3) a QTc threshold of 450 ms was used to differentiate normal from prolonged QT-intervals.

As inexperienced ECG-readers, 151 2\(^{nd}\) year medical students were willing to
cooperate after they were informed of the aim and nature of the study. The students were presented our method in 10 minutes and they received Figure 2. Subsequently, the students were asked to study the four ‘Viskin ECGs’, measure the QT and QTc-interval and determine whether the QTs were normal or prolonged. To assess reproducibility, 71 students were willing to measure the ECGs again four months later. This time however, they only received Figure 2 as guidance without further explanation.

The results of the students were first interpreted using the results of the LQTS-experts consulted by Viskin et al. The range of QTc values and the classification as either a normal or prolonged QT of these LQTS-experts were defined as correct results. Then we compared the students with the other physicians consulted by Viskin et al. These 877 physicians were located in university hospitals in 12 countries across the world (Australia, Austria, Brazil, Canada, China, England, France, Israel, Japan, Mexico, Paraguay, and the United States). The physicians were grouped as following; 1) arrhythmia specialists (n=106, cardiac electrophysiologists or cardiologists whose main activity is the treatment of cardiac arrhythmias); 2) cardiologists (n=329); and 3) noncardiologists (n=442, physicians in all

**Figure 1** The Viskin ECGs

ECGs A and B are from congenital LQTS patients, ECGs C and D are from two healthy females. Reproduced from Viskin et al. with permission.
fields of internal medicine except cardiology). The last group consisted of internists (33%), neurologists (16%), pediatricians (15%), emergency medicine or intensive care specialists (18%), gastroenterologists (5%), and others (13%). Analyses were performed in SPSS 15.0 (SPSS inc., USA). As measure of interobserver agreement we used the kappa coefficient. Kappa values above 0.8 were considered to present excellent agreement, whereas values below 0.4 were considered to present low agreement.

RESULTS

The student results for the first and second test are summarized in Table 1 and 2. Correct classification of all the four ECGs with a QTc threshold of 450ms to distinguish between

### Table 1: Student results on ECG A+B

<table>
<thead>
<tr>
<th>LQTS expert QTc range</th>
<th>ECG A (460–530)</th>
<th>ECG B (454–520)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student test number</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student QTc mean±SD (ms)</td>
<td>514±25</td>
<td>526±37</td>
</tr>
<tr>
<td>Student QTc range (ms)</td>
<td>449–589</td>
<td>451–616</td>
</tr>
<tr>
<td>Student correct QTc (%)</td>
<td>76</td>
<td>61</td>
</tr>
<tr>
<td>Student correct QT classification (%)</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

Student results during the first (n=151) and second test (n=71) for ECG A and B as compared with the results of the LQTS experts (who only assessed the ECGs once). Any QTc value of the students within the range of QTc values provided by the LQTS experts is regarded as a “correct QTc” and the LQTS expert classification of the QT interval as either normal or prolonged is regarded as the “correct QT classification.” The data presented are the mean, standard deviation (SD), and range of the student QTc assessments (all in milliseconds) and the percentage of students who entered a correct QTc and/or QT classification during their first and second test.
normal and prolonged QT-intervals, was achieved by 71% of the students during the first test. The subset of students in the first test who also participated in the second test, achieved 80% correct classifications on all the four ECGs during the first test. In the second test, 77% of the students correctly classified the four ECGs. In Figure 3 the student results have been implemented in the results achieved by the 106 arrhythmia experts (62% correct classification for ECG A-D) and the 771 cardiologists and non-cardiologists (both <25% correct classification for ECG A-D)\textsuperscript{4}.

The students’ interobserver agreement was comparable for the first and second test with kappa coefficients of 0.82 and 0.78 respectively. The LQTS-experts had a kappa coefficient of 0.82, whereas the arrhythmia experts had a kappa coefficient 0.44 and the cardiologists and non-cardiologists both had a kappa coefficient <0.3.

**DISCUSSION**

In this proof-of-principle study we found that inexperienced ECG-readers are able to rather accurately, uniform and reproducible diagnose prolonged and normal QT-intervals on four ECGs with this, apparently, easy to learn method of a tangent for end of the T-wave\textsuperscript{7} and Bazett’s correction for heart rate. It should be noted that the students were compared with physicians of whom probably the majority did not use this method of a tangent in combination with Bazett’s correction. In addition, the physicians got only one opportunity to perform the measurements and were only prepared on assessing QT-intervals on the basis of their medical training and experience as professionals in arrhythmias, cardiology or internal medicine.

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**Table 2** Student results on ECG C+D

<table>
<thead>
<tr>
<th>LQTS expert QTc range\textsuperscript{4}</th>
<th>ECG C</th>
<th>ECG D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>386–430</td>
<td>380–414</td>
</tr>
<tr>
<td>Student test number</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student QTc mean±SD (ms)</td>
<td>420±18</td>
<td>435±25</td>
</tr>
<tr>
<td>Student QTc range (ms)</td>
<td>381–493</td>
<td>451–498</td>
</tr>
<tr>
<td>Student correct QTc (%)</td>
<td>75</td>
<td>53</td>
</tr>
<tr>
<td>Student correct QT classification (%)</td>
<td>97</td>
<td>84</td>
</tr>
</tbody>
</table>

Student results during the first (n=151) and second test (n=71) for ECG C and D as compared with the results of the LQTS experts\textsuperscript{4} (who only assessed the ECGs once). Any QTc value of the students within the range of QTc values provided by the LQTS experts is regarded as a “correct QTc” and the LQTS expert classification of the QT interval as either normal or prolonged is regarded as the “correct QT classification.” The data presented are the mean, standard deviation (SD), and range of the student QTc assessments (all in milliseconds) and the percentage of students who entered a correct QTc and/or QT classification during their first and second test.
LQTS is a prevalent disease and physicians in all fields of medicine may well be confronted with a patient with possible LQTS. Risk of sudden cardiac death and Torsades de pointes in LQTS is thought to be largely dependent on the magnitude of prolongation of the QT-interval.\textsuperscript{2,8,9} The cornerstone of a LQTS diagnosis starts with a careful history, physical examination and QT-assessment on the ECG. A history of palpitations, dizziness, seizures, syncope or aborted sudden cardiac death, or a family history of LQTS or sudden cardiac death, are among the most important clinical aspects.\textsuperscript{2,4,8,9} Physicians should also be well aware of the many cardiovascular and non-cardiovascular drugs that may induce acquired LQTS.\textsuperscript{6} Unfortunately, the majority of physicians appear to misinterpret QT-intervals.\textsuperscript{4,5} Moreover, many LQTS-experts doubt the accuracy of computer measurements.\textsuperscript{5} This may result in both physician induced harm, e.g., unnecessary initiation of severe emotional stress, pharmacological treatment or implantation of implantable cardioverter defibrillators,\textsuperscript{5} and on the other hand erroneous reassurance of patients at risk for sudden cardiac death.

Accurate QT-assessment using a simple method thus seems warranted. With this study we show that it is possible to teach inexperienced ECG-readers a rather accurate method
to assess the QT-interval on this (very) limited number of ECGs. Notwithstanding this fact, difficulties will unavoidably arise when confronted with biphasic T-waves, arrhythmias or conduction disturbances, especially for inexperienced ECG-readers. Nonetheless, with the use of this method, physicians confronted with an ECG should be able to better stratify their patients’ (drug induced or congenital) risk for sudden cardiac death due to LQTS.

We believe that further studies into the use of the ‘tangent method’ with Bazett’s correction for assessment of the QT-interval and the risk for sudden cardiac death due to LQTS, are to be recommended. Meanwhile, this method may be informative for all physicians who interpret an ECG and aim to measure the QT-interval.

Acknowledgements
We are thankful to the students and their teachers for the kind cooperation.

REFERENCES

6 List of drugs that prolong the QT interval and/or induce Torsades de Pointes ventricular arrhythmia. University of Arizona Health Sciences Center 2006; Available at: URL: http://www.qtdrugs.org/. Accessed 4 March 2008.