Evaluation of the Malfunctions of a Clinical Decision Support System Dependent on Electrocardiograms and Measurement of the QT Interval

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***Abstract*—Malfunction of clinical decision support (CDS) systems could lead to undesirable consequences. We evaluated CDS malfunctions associated to the use of electrocardiograms (ECG) as data source to detect a delta in the corrected QT interval (QTc) ≥ 60 milliseconds (QTc current ECG minus QTc previous ECG). Our preliminary results showed that several common clinical conditions can cause changes in the electrocardiogram and result in errors when calculating the QTc interval and subsequently the delta QT between 2 serial ECGs. These errors cannot be easily identified by the electronic systems and are a source of CDS malfunction.**

Keywords-QT prolongation; electrocardiography; decision support systems; prognosis.

I. INTRODUCTION

Clinical decision support (CDS) systems integrated with the electronic health record (EHR) have the potential to enhance patient safety, improve quality of care, and decrease cost [1]. These systems are excellent tools to screen for rare but potentially life-threatening conditions. However, their accuracy depends on the structured data available in the EHR. If these data have errors, the CDS systems may be unable to provide accurate recommendations, or even worse, could provide false recommendations leading to unintended consequences for patients and clinicians.

Prolongation of the QT interval in the electrocardiogram (ECG) is a rare clinical condition that is an independent risk factor for Torsades de Pointes (TdP), a ventricular arrhythmia that can cause syncope, seizure or sudden cardiac death. QT prolongation can be congenital (long QT syndrome) or secondary to several medications, electrolyte abnormalities, and comorbidities. Because of these risks, international guidelines [2] recommend the use of electronic systems to detect potentially arrhythmogenic QT prolongation in hospitalized patients. QT prolongation is defined as a heart-rate corrected QT (QTc) value > 470 milliseconds (ms) in men and > 480 ms in women. For both genders, a QTc > 500 ms is considered potentially life threatening and is associated with a 2- to 3-fold higher risk for TdP. As the QT interval is relatively stable over the course of one's life, a delta QTc > 60 ms on serial ECGs is a potential warning sign, reflecting new/additional QT stressors might have occurred. Our institution has developed and implemented several CDS interventions to identify high risk patients showing QT prolongation, and provide appropriate management to prevent complications [3]. Herein, we present our preliminary results of the evaluation of the CDS malfunctions associated to the use of ECGs as the data source to detect a delta QTc ⩾ 60 ms.

II. METHODS

We evaluated a CDS system (QT Alert System) integrated with the EHR designed and implemented to improve awareness of a new clinically significant increase of the QTc by ⩾ 60ms in two consecutive ECGs. All ECGs were obtained and initially analyzed using the MUSE Cardiology Information System (GE Healthcare), which provided initial measure of the QT interval and QTc value. All electronically generated reports were evaluated by an ECG technician trained in ECG interpretation and, where needed, corrected. All pediatric and questionable abnormal ECG findings were evaluated subsequently by a pediatric or adult cardiologist. The QT Alert System screened all ECGs transmitted to the EHR to detect a delta QTc ⩾ 60ms by comparing the last two ECGs, and if positive, alerted the ordering provider (outpatient) or the primary hospital service (inpatient) by sending a semi-urgent inbox message. All event data were electronically stored for reporting.

A preliminary review of the ECGs was done using electronic searches to identify events with potential errors in measurement of the QTc focusing on extreme outliers. A sample of 50 alerts (100 ECGs) was reviewed independently by two physicians (TDG and NL), who manually re-calculated the QTc and assessed the ECGs for potential sources of errors that could have led to an erroneous delta QT. The ECG pairs were selected for review when the time between the ECGs was less than 7 days and (1) both QTc > 500 ms or (2) previous QTc < 360 ms and current QTc >500ms. These criteria were chosen because of the extreme QTc changes. The kappa statistic for initial agreement between the two reviewing physicians was 0.432. All differences were resolved by mutual consensus.

III. RESULTS

Overall, we analyzed 6,798 events (inbox messages) in 6,039 unique patients (52.2% male, mean age 60.1 years, SD ± 19.5 years) over a 6-year period. Patients could have more

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TABLE I. DISTRIBUTION OF THE EVENTS BASED ON THE QTC VALUE, N (%).

Previous ECG	Current ECG		
	QTc <360	QTc 360-500	QTc >500
QTc <360ms	10 (0.1%)	439 (6.5%)	43 (0.6%)
QTc 360-500ms	None	3132 (46.1%)	3000 (44.1%)
QTc >500ms	None	none	174 (2.6%)

than one event. The messages were sent to 6,434 unique providers. The time interval between consecutive ECGs was highly variable; for 27.35% of alerts, the interval was less than 2 days, 23.4% between 2 to 7 days, 34.25% between 8 to 365 days, and 15.0% between 1 and 5 years. Table I shows the distribution of the events based on the QTc value of the ECGs. A large proportion of events (47.3%) occurred with a current QTc > 500 ms that by itself was a risk factor for complications. A few events (n = 10; 0.1%) occurred with both QTc values below 360 ms (short QTc). Some events (n = 43; 0.6%) showed a very large delta QTc (mean delta QTc = 237 ms; SD = 89 ms).

TABLE II. CAUSES OF ERRORS IN MEASURING THE QTC.

Cause	N	%
Permanent pacemaker	28	26.92
Flat T-waves	20	19.23
Sinus tachycardia	12	11.54
Right bundle branch block	8	7.69
Atrial tachycardia	7	6.73
Supraventricular tachycardia	6	5.77
Cardiac ischemia	5	4.81
Ectopic beats	4	3.85
Acute myocardial infarction	3	2.88
Bradycardia	3	2.88
Temporary pacemaker	3	2.88
Atrial fibrillation	2	1.92
Atrial flutter	2	1.92
Cardiac arrest	1	0.96

Table II shows the result of the manual review by the clinicians. The most common causes of errors were the presence of a pacemaker, flat T-waves, tachyarrhythmia and bundle branch block.

IV. DISCUSSION

Our results suggest that ECG data can be a source of malfunction of CDS systems. In the case of detecting QTc abnormalities, several common clinical conditions (Table II) can change the morphology of the QT wave or the heart rate introducing significant errors when the QTc is measured by an electronic system.

The ECG is the source of high value data related to the cardiac function and can be used to identify patients at risk for complications due to abnormal changes in the QT interval. However, these data are unstable and influenced by several factors that may not be easily recognized by a CDS system. Nevertheless, most of these errors are detected easily by a clinician reviewing the ECG.

To improve the accuracy of CDS systems that use ECG data, it may be necessary to use additional EHR data indicating new changes of the patient's clinical condition. Potential changes include identifying new interventions (i.e., pacemakers), new cardiac events (i.e., ischemia, arrhythmias), or transfer to a different clinical setting (i.e., monitor bed, intensive care unit, operating room). Better standardization of ECG interpretation and reporting [4] is also needed to minimize data errors. These changes could help in the design of more accurate, context sensitive CDS systems able to improve performance while decreasing burden and alert fatigue.

In conclusion, erroneous ECG data can impact significantly the outcome and the clinical recommendations provided by CDS systems. These malfunctions could lead to alert fatigue and mistrust of the recommendations provided by CDS systems.

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