Background  Many medications commonly used in hospitals can cause prolonged corrected QT interval (QTc), putting patients at risk for torsade de pointes (TdP), a potentially fatal arrhythmia. However, documentation of QTc for hospitalized patients receiving QT-prolonging medications is often not consistent with American Heart Association standards.

Objective  To examine effects of education and computerized documentation enhancements on QTc documentation.

Methods  A quasi-experimental multisite study among 4011 cardiac-monitored patients receiving QTc-prolonging medications within a 10-hospital health care system was conducted to compare QTc documentation before (n = 1517), 3 months after (n = 1301), and 4 to 6 months after (n = 1193) an intervention. The intervention included (1) online education for 3232 nurses, (2) electronic notifications to alert nurses when a patient received at least 2 doses of a QT-prolonging medication, and (3) computerized calculation of QTc in electronic health records after nurses had documented heart rate and QT interval.

Results  QTc documentation for inpatients receiving QTc-prolonging drugs increased significantly from baseline (17.3%) to 3 months after the intervention (58.2%; P < .001) within the 10 hospitals and had increased further 4 to 6 months after the intervention (62.1%, P = .75). Patients at larger hospitals were significantly more likely to have their QTc documented (46.4%) than were patients at smaller hospitals (26.2%; P < .001).

Conclusion  A 3-step system-wide intervention was associated with an increase in QTc documentation for patients at risk for drug-induced TdP, and improvements persisted over time. Further study is needed to assess whether increased QTc documentation decreases occurrence of drug-induced TdP. (American Journal of Critical Care. 2015;24: e6-e15)
In 2010, the American Heart Association (AHA), in conjunction with the American College of Cardiology Foundation, published a scientific statement for prevention of torsade de pointes (Tdp) in hospitals. This statement provided recommendations for monitoring the QT interval corrected for heart rate (QTc) for at-risk hospitalized patients in hope that detection of an increasing QTc may identify patients at risk for Tdp, a potentially fatal arrhythmia. Of particular emphasis was the recognition that many commonly administered drugs can prolong QTc, putting patients at risk for Tdp. By identifying patients receiving these drugs, appropriate QTc monitoring can be performed and prescribers alerted to consider discontinuing the drug.

Hospital leaders may find it challenging to implement guidelines without overburdening clinicians. Findings from a study conducted among 17 hospitals with 1816 patients demonstrated that only 21% of patients with an indication for QTc monitoring had a QTc documented. We present the results of a quasi-experimental, multisite study to improve QTc documentation according to AHA recommendations.

Background

Prolongation of QT Interval

On the electrocardiogram (ECG), the QT interval represents both depolarization and repolarization of the ventricles. For practical clinical purposes, however, the QT interval is used as an indirect measure of ventricular repolarization because the start of the QRS complex is easy to identify; thus, measurement of the QT interval is initiated at the beginning of the QRS complex and terminated at the end of the T wave. Patients with a prolonged QT interval are at risk for Tdp, a polymorphic ventricular tachycardia characterized by twisting points of the QRS complex and preceded by a prolonged QTc interval (>0.50 seconds). Although this type of ventricular tachycardia does not occur frequently, it has the potential to be fatal.

In addition to some patients having a genetic susceptibility to a prolonged QT interval, many drugs can prolong the QT interval. These drugs include medications from a variety of classes, including antibiotics, antipsychotics, and opiate agonists, in addition to the more well-recognized cardiac drugs such as dofetilide, ibutilide, and sotalol. A full list identifying these drugs is provided by CredibleMeds, AZCERT Inc, on their website (www.qtdrugs.org), which is updated on a regular basis. The potential QT-prolonging effect of these drugs is exacerbated by the patient receiving more than 1 QT-prolonging medication as well as by administration via an intravenous route.

Indications for QTc monitoring include initiation of a new QT-prolonging drug, overdose from any potentially QT-prolonging drug, new-onset bradyarrhythmias, and severe hypokalemia or hypomagnesemia. A risk-benefit analysis should be done for individual patients. Important questions for the prescriber include the following: Can a different drug be used, and, if not, does benefit outweigh risk?

Computerized Alerts

Some hospitals and clinics have attempted to use computerized best-practice advisories (BPAs) to increase documentation of adherence to clinical guidelines. BPAs are automated decision support tools in electronic health records (EHRs) that are presented at the point of care to encourage providers to take specific actions. The efficacy of BPAs in increasing nursing documentation for QTc among hospitalized inpatients has not been explored.
Three retrospective studies were identified in which computer alerts were evaluated for usefulness in identifying patients prescribed QT-prolonging medications. Van der Stijn et al. reported that among 168 patients with drug-drug interaction alerts on QTc prolongation, a substantial number of the alerts were overridden by the physician. Tisdale et al. evaluated alerts to pharmacists when QT-prolonging medication was prescribed among 2400 cardiac unit inpatients. Pharmacists had the option to override the alerts and provide the medication or to consult the prescriber for possible additional monitoring. Findings included decreased prescribing of QT-prolonging medications with the computer alert. Haugaa et al. evaluated an institution-wide QT alert system that identified ECGs with QTc greater than 0.50 seconds (n = 1145), resulting in a “semi-urgent” e-mail alert to the prescriber. Although valuable data were gleaned regarding predictors of prolonged QT intervals and mortality, alerts occurred via e-mail rather than directly at the point of care; adjustment in treatment was not reported.

One prospective study was identified. Ng et al. randomized 149 patients to a standard care group versus an intervention group (addition of algorithm by pharmacist). QTc interval prolongation occurred less often in the intervention group (19%) than in the standard care group (39%), and the algorithm-generated recommendations received a 70% acceptance rate from the physician team. Authors reported that total cost was not significantly different between groups.

In contrast to past investigators, who used daily 12-lead ECGs to compare QTc intervals, our goal was to avoid relying on daily ECGs, as these are not always ordered for our patients and may contribute to extra cost. Relying on nurses to monitor for QTc prolongation by using real-time ECG monitoring allowed QTc prolongation to be identified within 8 to 16 hours so that any prolongation could be addressed before the next dose of medication was administered. To our knowledge, ours is the first interventional study in which computer alerts for QT-prolonging medications are provided to the end user, that is, the nurse who is ultimately going to administer the medication or withhold the medication, depending on the QTc.

### Methods

#### Purpose

The objective of this study was to examine the impact of education and computerized documentation enhancements on QTc documentation.

#### Design

A quasi-experimental, multisite study was conducted to compare QTc documentation at baseline, for the first 3 months after the intervention, and from 4 to 6 months after the intervention. The institutional review board for the hospital system determined that the study qualified for exempt status.

#### Setting and Sample

The study was implemented at 10 Midwestern hospitals within Allina Health, ranging from small (rural hospital staffed for 25 beds) to large (urban hospital staffed for 626 beds). Inclusion criteria included EHRs of adult patients on ECG monitoring who received at least 2 QT-prolonging medications. Exclusion criteria included patients with atrial fibrillation or flutter, based on feedback from nurses at the pilot site who found the QT interval so variable that precise measurement was difficult. Although the intervention targeted nurses who cared for adult patients, smaller rural hospitals occasionally admit pediatric patients to shared units; thus, it is possible that a few QTc documentations for monitored pediatric inpatients who received at least 2 QT-prolonging medications were included in the analyses. The new QTc documentation policy and education were made mandatory for all nurses providing ECG monitoring; thus 3232 nurses completed the related QTc online education. Epic Systems EHR had been in place for 4 years before the intervention, is tailored by Allina Health, and is referred to within the organization as Excellian.

#### Process for Organizational Change

Part of the challenge of integrating QTc measurement within the EHR was the complexity of working within a 10-hospital system. The initial EHR system did not support automatic calculation of the QTc and, once manually calculated by the nurse, the measurement fell to the bottom of the EHR documentation flow sheet. A request was made to the EHR in-patient work group for a 3-step approach to standardizing QTc documentation; agreement had to be obtained from key nurses at each hospital. A system-wide ad hoc committee was established, proposals were made using SBARs (Situation, Background, Assessment, Recommendation), and multiple meetings occurred with leadership, management, and nursing councils.
Based on the online list by CredibleMeds, AZCERT Inc (www.qtdrugs.org), a QT-prolonging medication list was identified and approved by the system-wide pharmacist group.

Two units from different hospitals served as pilot sites for the BPAs and automatic QTc documentation. An update was provided in the hospital newsletter to alert prescribers to the practice change (see Table). Physicians at 3 of the hospitals agreed to be prescriber point-persons and were available to answer questions from other prescribers. Additionally, a lead clinical nurse specialist and pharmacist were listed as point persons for questions or feedback.

**Interventions: A 3-Step Approach**

A 3-step approach to improving documentation to be consistent with AHA recommendations for QTc monitoring was employed: (1) a BPA that automatically notifies the nurse when a patient is receiving QT-prolonging medications, reminding the nurse to monitor QTc, (2) automatic, computerized calculation of QTc once the nurse enters the QT interval and the heart rate into the EHR, and (3) mandatory online education module on QTc monitoring.

1. **BPA for Patients at Risk for TdP.** Both a safety banner and an active BPA alert were introduced as automatic EHR features, reducing the burden for nurses to recall from memory or look up which medications might cause prolongation of the QT interval. The resulting electronic safety banner is displayed when a nurse opens the EHR of a patient meeting the criteria (Figure 1).

   This safety banner is further supplemented by an active BPA that is triggered if the nurse forgets to document the QTc and scans the bar code of a QT-prolonging medication (Figure 2). This BPA appears on the Medication Administration Record when the nurse attempts to administer QT-prolonging medication without a QTc documented within a pre-specified time frame. However, if the nurse determines that the patient’s QT is not measurable (eg, in a delirious patient too active for proper waveform tracing), the nurse can select the option “Not appropriate for patient.”

2. **Automatic, Computerized Calculation of QTc.** An automatic, computerized calculation for QTc was added as a function within the EHR. When a nurse documents heart rate on the EHR via the Document Flow Sheet, an adjacent row reads: “QTc documentation indicated?” (Figure 3). If yes, a row for QTc is populated. Subsequently, when the nurse enters the heart rate and the QT interval, the QTc in this row is automatically calculated.

   It is important that clinicians use a QT interval that is corrected for heart rate (QTc) so that measurements can be compared regardless of changes in heart rate. Bazett’s formula\(^\text{10}\) is commonly used to calculate QTc:

   \[
   \text{QTc} = \frac{\text{QT}}{\sqrt{RR}}
   \]
an automated QTc measurement, but this feature is not uniformly available at each hospital. Some intensive care units at our sites have the heart rate from patient monitors sent to the EHR directly from monitoring equipment. However, nurses at these sites are required to validate the data before accepting it into their electronic documentation.

Nurses at some sites use electronic calipers to routinely measure waveforms, whereas others use hand-held calipers for manual measurement on a paper waveform strip that is then scanned into the patient’s record upon hospital discharge. A mutually agreed upon decision was made to require documentation of QTc in a uniform place on the documentation Flow sheet (Figure 3), regardless of the method used to measure the QT interval. This way, all health care providers can consistently and quickly find QTc documented in the same EHR flow sheet regardless of the hospital site.

(3) Mandatory Online Education Module. After the computerized QTc calculation and BPAs were tested by pilot sites, a mandatory online education module commenced. The module was developed by the first author (K.E.s.) with input from 2 clinical nurse specialists. The content was based on the AHA scientific statements.

Before the intervention, nurses at many of our sites found it necessary to use calculators to determine the square root of the RR interval. Bazett’s formula, in a revised form, was adapted from recommendations from Sommargren and Drew and entered into the EHR as:

\[ QTc = \sqrt{HR/60} \times QT \text{ interval (in seconds)} \]

As a result, nurses were able to use the EHR to type in QT and HR, and the QTc was automatically calculated in the row below.

Our hospitals have ECG monitoring equipment from more than 1 vendor. Some monitors provide
shots of changes in the EHR), emergency treatment of Tdp, and identification of QTc of 0.50 seconds or greater as a clinically significant cut-off (for men or women) for which nurses would call the prescriber. The module ended with practical question/answer slides, some of which had been elicited from nurses at the pilot sites.

Before implementation of the education module, 9 nurses pilot tested the module for clarity, completing it in a mean of 23 minutes. After online education, all nurses had the opportunity to give feedback about the module. A large number of nurses (n = 598) provided online feedback, which was predominately positive. The vast majority of nurses in our hospitals are union members; thus the system we used was consistent with the hospital/union agreement to package any mandatory education into an online system, which is delivered quarterly and paid on the basis of the mean number of minutes completed in a small pilot test. A total of 3232 nurses completed the related QTc online education at work or at home within the final quarter of 2011, before the January 2012 implementation of QTc BPAs.

Data Collection

Data for this study were extracted from Clarity, Epic’s reporting tool. We selected confirmed hospital inpatients admitted from July 1, 2011 through June 30, 2012. To be included in the analysis, the patient had to receive at least 2 doses of the same QT-prolonging medication at some point during their hospital stay. Case selection was further narrowed to include only patients who underwent ECG monitoring while taking a QT-prolonging medication. The main outcome measure of interest was whether nurses documented QTc measurements in patients’ EHRs during the hospital stay. Secondary outcomes included assessing for a relationship between hospital size and QTc documentation, as well as counting the number of BPAs triggered during hospital stays. Hospitals were categorized as large (3 hospitals staffed for ≥250 beds) versus small (7 hospitals staffed for <250 beds).

Data Analysis

A factorial logistic regression analysis, using SPSS Statistics 20 software, was conducted. The 2 independent variables were timing relative to the intervention (baseline, the first 3 months after the intervention, and 4-6 months after the intervention) and hospital size (1 = large vs 0 = small). QTc documentation was the dependent variable (1 = documented, 0 = not documented). Alpha was set at the standard .05 level.

Results

QTc Documentation

The number of inpatients who had ECG monitoring while receiving QT-prolonging medications was 1517 (out of 2762, 55%) at baseline, 1301 (out of 2343, 55%) up to 3 months after the intervention, and 1193 (out of 2114, 56%) 4 to 6 months after the intervention. The percentage of these patients who had appropriate QTc documentation was 17.3% at baseline (263/1517) and increased significantly to 58.2% (757/1301) in the 3-month period after the intervention (Wald [df = 1] = 58.31, P <.001). QTc documentation continued to increase to 62.1% (741/1193) 4 to 6 months after the intervention. This second increase was not statistically significant (Wald [df = 1] = 0.10, P =.75).

Large Versus Small Hospitals

Inpatients in larger hospitals were significantly more likely to have QTc documentation (46.4%) than inpatients at smaller hospitals (27.2%) (Wald [df = 1] = 18.02, P <.001). However, the interaction between time relative to the intervention and hospital size was not significant (Wald [df = 2] = 3.07, P =.22). That is, nurses at larger hospitals had higher rates of QTc documentation than nurses at smaller hospitals from baseline to 4 to 6 months after the intervention. However, nurses at both large and small hospitals had significant increases in QTc documentation after the intervention (Figure 4).
BPAs Triggered

Active BPAs were triggered whenever a nurse attempted to document administering a QT-prolonging medication without first documenting a QTc within the prescribed time frame for the medication. A number of BPAs (n = 39) were triggered during the baseline data collection period because of the 2 pilot sites going live with the alerts. After the intervention, BPAs were frequently triggered: 762 times during the first 3 months after the intervention and 746 times at 4 to 6 months after the intervention.

Discussion

Characteristics of Patients

Clearly not all patients receiving QT-prolonging medications were receiving ECG monitoring; many were in nonmonitored units and the health care provider did not consider them at risk for Tdp. This finding is as expected. Drew et al1 explained that healthy patients without a prolonged QT interval at baseline and without other risk factors for Tdp (ie, normal electrolyte levels) do not automatically need to receive ECG monitoring. Our intervention did not appear to be associated with a subsequent increase in the percentage of patients for whom ECG monitoring was ordered.

As previously mentioned, we excluded patients in atrial flutter or fibrillation, based on feedback from pilot site nurses who found the QT interval so variable that measurement was difficult. This decision was supported by guidelines from Rautaharju et al.11 For clinicians who choose to monitor QTc in these patients, the clinician may select the shortest and longest QTc and obtain a mean.1 Alternatively, prolonged QTc is recognized if the QT interval exceeds half the RR interval,1 or is increased by more than 0.06 seconds. In these cases, nurses must communicate clearly the method selected to recognize prolonged QTc so that staff on each shift can be consistent.

Impact of Interventions

A statistically significant increase in documentation was noted after the intervention. The fact that no further statistically significant increases were found from 4 to 6 months after the intervention could reflect 2 possibilities. First, this finding could reflect that we had very few late adopters of the change in practice owing to the intentional preplanned “marketing” and mandatory nursing education with “go-live” occurring simultaneously at 10 sites. Alternatively, this finding could reflect that we were less affected by the concept of alert fatigue for this particular BPA, thanks to the baseline “buy-in” from nurses for its helpfulness and credibility. Regardless, the effect of the intervention was sustained at 6 months after the intervention.

Although some researchers have demonstrated improved outcomes with BPAs to improve accurate recording of inpatient weights12 and appropriate administration of influenza vaccines,13 others have reported poor outcomes, with the primary reason being alert fatigue.14-16 Taegtmeyer et al15 evaluated electronic drug-drug interactions for cardiovascular surgery patients and reported that 89% were not clinically relevant. Embi and Leonard16 discussed low levels of documentation after intervention as having multifactorial causes, which could be further understood by using qualitative study of end users’ perceptions of BPAs. A lack of clinician buy-in to a BPA request for screening or documentation was illustrated by Sequist et al,14 whose electronic alerts (based on Framingham Risk Score) did not improve adherence to documentation according to guidelines for chest pain management. Investigators surveyed clinicians at the study’s end, finding that only 40% of their clinicians perceived the Framingham Risk Score to be “often” valid.

Phansalkar et al17 provided clear principles important to the design and implementation of effective clinical decision support alerts. Sidebottom et al18 conducted qualitative focus groups to better understand end-users’ preference for BPAs among staff nurses using a newly implemented EHR. Staff nurses preferred dashboard style alerts in which they could immediately address the desired intervention. Nurses requested the following: electronic “pop-ups” be used only for time-sensitive issues related to high-level importance measures (1-time event rather than part of routine); alerts perceived as trustworthy; and clear education for any EHR adaptations. Our BPAs, therefore, were designed incorporating these requests from staff nurses.

In the present study, smaller hospitals had lower QTc documentation rates than larger hospitals had. We hypothesize that larger hospitals may have a more formal method of instituting change; however, reasons for this finding need more exploration. One of our smaller hospitals is currently developing an initiative to provide review of guidelines for QTc documentation. This update will include the annually updated, edited list prepared by our pharmacists for QT-prolonging medications so that the list of
medications triggering the BPAs will include only medications currently in use at our facility.

The fact that several staff nurses in a leadership council requested that QTc reminders be built into the EHR provided us with enough initial buy-in to gain momentum to raise QTc documentation from 17.3% to 62.1%, a respectable increase in a short time for a large organizational change. Reasons why this 62.1% was not higher could include alert fatigue, the fact that the nurses have several other BPAs competing for their attention. Another reason could be that the varying time frames during which the QTc documentation active alerts fired (8 hours, 12 hours, or 24 hours) confused the nurses. These varying time frames were assigned by the pharmacy to correspond to the QT-prolonging drug’s half-life. However, since the study occurred, nurses have expressed that they prefer the consistency of an every-8-hour expectation for QTc documentation, regardless of drug type. We are in the process of making QT-prolonging medications triggering the BPAs will include only medications currently in use at our facility.

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Limitations

Although Bazett’s formula has been used for decades, more recently developed formulas for calculating QTc are available and may provide greater accuracy for extreme heart rates.11 Limitations include the fact that this study occurred using a single EHR in hospitals employing bar-code medication scanning. Replication of this study in other settings or systems that use different EHRs and medication administration processes is encouraged. Future researchers should collect additional data to glean more understanding of clinical significance: number of calls to prescriber and resulting medication changes.

Conclusions

Our study demonstrated that a 3-step approach (incorporating BPAs, automated computerized calculation, and education on QTc monitoring) was followed by a significant increase in QTc documentation according to AHA guidelines. Further study is needed to evaluate whether BPAs change prescribing of QT-prolonging medications and whether use of BPAs is associated with decreases in the occurrence of TdP.

ACKNOWLEDGMENTS

We thank Mary Lambert and Melissa Portz at Allina Clinical Decision Support as well as Beverly Collins and Maureen Smith (in memoriam).

FINANCIAL DISCLOSURES

None reported.

eLetters

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SEE ALSO

For more about QT intervals, visit the Critical Care Nurse Web site, www.ccnonline.org, and read the article by Pickham, “Understanding and Documenting QT Intervals” (August 2013).

REFERENCES


