IMPROVING NURSES' CORRECTED QT INTERVAL MONITORING ON A TELEMETRY UNIT

UNIVERSITY OF HAWAIʻI AT MĀNOA NANCY ATMOSPERA-WALCH SCHOOL OF NURSING

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Abstract

Importance: Corrected QT interval (QTc) prolongation was a type of ventricular tachyarrhythmia that could result in torsades de pointes (TdP) and sudden cardiac death. Recommendations and ongoing education for QTc interval monitoring and TdP for telemetry nurses were limited and variable. Improvement of nurses' QTc interval monitoring allowed an opportunity to initiate escalation of care in a timelier manner, improve the prevention of TdP and ultimately improve the overall mortality rate in a hospital setting.

Methods: An evidence-based QTc interval monitoring and TdP educational presentation was developed according to current guidelines and practice standards for electrocardiogram monitoring, with input from experts. The nursing staff on the study telemetry unit received education on QTc interval monitoring and TdP. A knowledge and self-efficacy assessment was administered to nurses at baseline and immediately after the educational intervention.

Results: Participants' knowledge improved after the educational intervention, with an overall average of 68.58% correct responses to knowledge assessment questions at baseline and 80.42% immediately after education. Similarly, participants' self-efficacy improved after the educational intervention, with an overall average score of 18.27 on a 30-point scale at baseline and 23.47 on a 30-point scale immediately after the intervention.

Discussion: This evidence-based QT educational presentation based on American Heart Association practice standards for QTc interval monitoring improved nurses' knowledge and self-efficacy with QTc interval monitoring and TdP. Project findings demonstrated that relying solely on education was insufficient, suggesting that a comprehensive approach would aim to enhance and ensure the integration of evidence-based practice standards into daily clinical practice.

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Improving Nurses' Corrected QT Interval Monitoring on a Telemetry Unit

Rate-corrected QT (QTc) interval prolongation led to ventricular arrhythmia known as torsades de pointes (TdP), which resulted in sudden cardiac death (SCD) (Barrett, 2015; Drew et al., 2010; Trinkley, Lee Page, Lien, Yamanouye, & Tisdale, 2013). Practice standards and scientific statements from the American Heart Association (AHA) and the American College of Cardiology Foundation (ACCF) recommended that hospital patients receiving drugs known to cause TdP, overdose from potentially proarrhythmic drugs, have moderate to severe electrolyte disturbances, or had new-onset bradyarrhythmia should receive QTc interval monitoring (Drew et al., 2004, Drew et al., 2010; Sandau et al., 2017). A prospective study of patients admitted to critical care units found nearly 69% of patients had one or more AHA indications for QTc interval monitoring, 24% of the patients developed QTc interval prolongation, and 57% of patients received at least 1 QT-prolonging drug (Pickham et al., 2010). Direct care nurses and nurse leaders involved in day-to-day patient care in the hospital were the ones best suited to implement QTc interval monitoring for these high-risk patients (Barrett, 2015). However, prior studies demonstrated that nurses' baseline ability to perform QTc interval monitoring was extremely poor (Funk et al., 2010; Pickham, Shinn, Chan, Funk, & Drew, 2012; Schwimer, Al-Zaiti, & Beach, 2022). Clearly, improving and maintaining nurses' QTc interval monitoring competency in congruence with AHA practice standards for electrocardiogram (ECG) monitoring was imperative.

For those at risk for TdP and SCD, being able to recognize risk factors for QTc interval prolongation, assess a patient's risk for QTc interval prolongation, and accurately perform QTc interval monitoring was essential to initiate and facilitate appropriate care escalation and intervention. Despite limitations that existed when using QTc interval prolongation as a

surrogate marker for TdP, such as interindividual variability in performing measurements, diurnal variability, and heart rate, the lack of a better predictive method for detecting TdP warranted its continued use (Trinkley et al., 2013). Due to the growing number of drugs associated with QTc interval prolongation as well as the sudden onset of TdP and its catastrophic nature, cautionary measures to prevent QTc interval prolongation and TdP were warranted (Trinkley et al., 2013). It was, therefore, crucial to provide evidence-based education on QTc interval monitoring and TdP for telemetry nurses to maximize the quality of care, patient safety, patient outcomes, and overall statistics of in-hospital cardiac arrest favorably (Funk et al., 2017; Trinkley et al., 2013).

Background

The QT interval (QTi), which approximated the time required for the ventricles to repolarize, was measured from the beginning of the QRS complex to the end of the T wave on a standard ECG and was influenced by heart rate. (Drew et al., 2004). A prolonged QTi was defined by AHA/ACCF as a QTc interval greater than the 99th percentile for females and males, which was >480ms and >470ms, respectively (Drew et al., 2010; Trinkley et al., 2013). However, many standard ECGs continued to label a QTc interval of >440ms as borderline QTc interval prolongation (Drew et al., 2010; Trinkley et al., 2013). A prolonged QTc interval was directly correlated with an elevated risk of TdP, a life-threatening hemodynamically unstable polymorphic ventricular tachycardia that could progress to ventricular fibrillation, causing most cases of SCD (Barrett, 2015; Drew et al., 2004, Drew et al., 2010; Sandau et al., 2017; Trinkley et al., 2013). Expert opinions highlighted the clinical significance of QTc duration >500ms as being associated with a higher risk for TdP (Sandau et al., 2017). The malignant arrhythmia TdP was linked to abnormally long repolarization times, which could be caused by certain conditions

and drugs (Drew et al., 2004; Sandau et al., 2017). Hospitalized patients were thought to have the greatest risk of QTc interval prolongation and TdP due to the increased prevalence of risk factors, such as electrolyte abnormalities, renal or hepatic dysfunction, and cardiovascular disease (Drew et al., 2010; Trinkley et al., 2013). The possibility of TdP could be anticipated by the detection of an increasing QTc interval and other premonitory ECG signs of impending arrhythmia in hospital units where patients were monitored continuously on ECGs (Drew et al., 2010). If increasing QTc intervals and other ECG signs of impending TdP were recognized by nurses, it then became possible for other members of the healthcare team to discontinue the offending drug (if any) and manage concomitant conditions (i.e., hypokalemia, bradyarrhythmia) to reduce the occurrence of TdP and SCD, respectively (Drew et al., 2010).

Guidelines for QTc interval monitoring were released in the 2004 AHA best-practice standards for ECG monitoring in hospital settings (Drew et al., 2004). Despite these and more recently updated recommendations in the updated AHA practice standards, a significant amount of ambiguity concerning QTc interval monitoring remained and underscored the need for expanded ECG monitoring to detect ventricular arrhythmias with the potential to cause SCD (Sandau et al., 2017). Although assessing the QTi/QTc had become a standard part of in-hospital monitoring, a consensus was lacking concerning specific measurement methods, heart rate correction methods, frequency of QTi/QTc measurement and monitoring, and patient selection (Sandau et al., 2017). Many hospitals had no established criteria or protocol for the implementation of QTc interval monitoring, and often not many nurses were aware that they needed to monitor the QTi/QTc, despite the fact that documentation of QTi/QTc interval trends could prevent drug-induced QTc interval prolongation and SCD (Barrett, 2015; Funk et al., 2010; Sandau et al., 2017). Studies showed nurses' baseline competency in QTc interval

monitoring was remarkably low (Funk et al., 2017; Pickham et al., 2012; Schwimer et al., 2022). Responses such as this indicated large knowledge gaps that called for a QTc interval monitoring and TdP educational intervention.

Problem Statement

Careful ECG monitoring played a crucial role in identifying deteriorating or decompensating conditions that had the potential to progress into life-threatening sustained ventricular arrhythmias. Early identification of such conditions could prompt timely interventions and treatments that could prevent cardiac arrest or enable a prompt response and effective management. In the healthcare setting, nurses held a unique position to provide QTc interval monitoring. They were responsible for complex continuous cardiac monitoring, obtaining, and reviewing electrolyte values, and administering potentially QT-prolonging medications. As a result, nurses should have been able to identify patients who required QTc interval monitoring and perform this type of monitoring reliably.

The telemetry units at the study institution had no in-service education for QTc interval monitoring and TdP. Previous practice was to rely on the nurses' existing baseline knowledge and self-efficacy to perform this type of monitoring reliably. During an informal needs assessment, two members of the electrophysiology team at Queen's Medical Center (QMC) – Punchbowl, Dr. David Singh, and Kailie Wong, APRN, were interviewed. These clinical leaders emphasized the importance of implementing an evidence-based educational session on QTc interval monitoring and TdP to enhance nurses' awareness, prevention strategies, and recognition of early warning signs of possible impending TdP. They believed that providing an in-service training session for telemetry nurses on QT prolongation predisposing factors and QTc interval monitoring would enable nurses to initiate timely escalation of care, improve TdP prevention

efforts, and ultimately contribute to a reduction in overall mortality rates (D. Singh, personal communication, August 29, 2022).

PICOT

For telemetry nurses in an acute care hospital in urban Honolulu (P), does the development of a 16-minute educational intervention focused on knowledge and assessment of QTc interval monitoring (I) result in (a) an increase in nurses' knowledge of and (b) an increase in nurses' self-efficacy in recognizing and providing appropriate QTc interval monitoring (O), as compared to the previous level of knowledge and self-efficacy prior to the educational intervention (C), utilizing a pre-posttest methodology at a single time point (T)?

Purpose and Objectives

The purpose of this quality improvement project was to develop and implement an evidence-based QT-educational presentation based on AHA practice standards for QTc interval monitoring to telemetry nurses at QMC-Punchbowl, aiming to improve their knowledge and self-efficacy with QTc interval monitoring and TdP. The project objectives included:

1. Creating an evidence-based QT-educational presentation for monitoring the QTc interval on a telemetry unit.
2. Assessing nurses' knowledge and self-efficacy regarding QTc interval measurement, monitoring, and risk.
3. Decreasing variability and uncertainty regarding practice standards for QTc interval monitoring
4. Promoting awareness and standardization of QTc interval monitoring with the long-term goal of reducing the risk for and prevention of TdP.

Framework

The Iowa Model of Evidence-Based Practice (Appendix A) served as the conceptual framework for this Doctor of Nursing Practice (DNP) project. This model guided clinical decision-making and evidence-based practice through a multi-step process. The first step in the Iowa model was to identify a problem where an evidence-based practice change might have been warranted. The next step in the Iowa model was to determine whether the issue at hand was a priority. Once the priority had been determined, the subsequent step involved forming a team of members that would help develop, evaluate, and implement the evidence-based practice change. The following step was to implement the intervention into a pilot practice change to ensure the change was feasible and would result in improved outcomes before full-scale implementation. The team continued to evaluate the practice change to watch for any deviation in practice or a decrease in outcomes (Iowa Model Collaborative et al., 2017).

The implementation of this DNP project followed this step-by-step process. Firstly, Dr. David Singh, an electrophysiologist at QMC - Punchbowl Campus, identified a need for increased awareness, recognition, and prevention of TdP among nurses to promote and improve prompt patient safety monitoring. Secondly, successful development required multidisciplinary team collaboration. The team members included Dr. David Singh (physician), Kailie Wong (nurse practitioner), and the author (nurse practitioner student). Next, a systematic review of the literature revealed evidence-based support for the intervention. Subsequently, the practice change was initially implemented on a telemetry unit and evaluated for changes in nurses' knowledge and self-efficacy on QTc interval monitoring. At the conclusion of this pilot quality improvement project, a plan for succession was established to ensure the continued utilization of beneficial components of the educational intervention beyond the initial implementation period.

Synthesis of the Evidence

Evidence Search

CINAHL, PubMed, and Google Scholar databases were used to search for evidence-based findings regarding the education of nurses on best practice standards for QTc interval monitoring. The search terms included "registered nurses," "QT monitoring," "QT prolongation," "torsades de pointes," "educate," "teach," "knowledge," "skill," "practice," "competence," and "attitude." Subject headings and Boolean strings such as "AND," "OR," and truncated terms were utilized to refine the literature search. To further refine the search, articles were limited to English language, human subjects, published within the last 20 years, and full-text availability. After refining the search, appropriately 195 articles were identified and reviewed for relevance. Articles that were not pertinent to the literature search topic were excluded from consideration, while those that were relevant and displayed good to fair strength of evidence were included. A total of 12 articles were selected for this literature synthesis.

Literature Synthesis

The Mosby's Quality of Evidence Rating System was utilized to critically appraise the selected articles and determine their level of evidence (see Table 1). The majority of the articles were classified as authority opinions and expert committee reports (level VII evidence) and case-controlled, cohort, and longitudinal studies (level IV evidence). This review also utilized randomized controlled trials, quasi-experimental designs, literature syntheses, and quality improvement projects.

Table 1. Mosby's Level of Evidence and Number of Relevant Articles

Mosby's Level of Evidence	Number of Articles
Level I: Meta-analysis	0
Level II: Experimental design (RCT)	2

Level III: Quasi-experimental design	1
Level IV: Case-controlled, cohort, longitudinal studies	3
Level V: Correlation studies	0
Level VI: Descriptive studies	0
Level VII: Authority opinion or expert committee reports	4
Other: Performance improvement, case reports, literature review, etc.	2

The final sample of articles (n=12) were reviewed individually for their topical focus, methods, sample, and main findings. The articles were then categorized into three main categories based on their content:

1. Current practice standards for QTc interval monitoring: These articles focused on describing the existing guidelines and recommendations for QTc interval monitoring in clinical practice. They discussed the importance of monitoring QTc intervals, the criteria for identifying prolonged QTc intervals, and the implications for patient safety.
2. Barriers to QTc interval monitoring: These articles examined the various barriers and challenges that hinder effective QTc interval monitoring by nurses. They identified factors such as lack of knowledge, inadequate training, time constraints, and organizational barriers that contribute to suboptimal monitoring practices.
3. Interventions and strategies to improve QTc interval monitoring among nurses: These articles explored different educational interventions, training programs, and strategies aimed at enhancing nurses' knowledge and skills in QTc interval monitoring. They discussed the effectiveness of these interventions in improving

nurses' competence and confidence in recognizing and managing QTc interval prolongation.

Each article in the sample was summarized and analyzed based on these categories, providing valuable insights into current practices, barriers, and potential interventions for improving QTc interval monitoring among nurses. For detailed information, please refer to Appendix B.

Current practice standards for QTc interval monitoring. Current practice standards for QTc interval monitoring emphasized the importance of assessing and documenting pertinent patient information, including QTi/QTc trends and medications that could prolong the QTc interval (Barrett, 2015). Prolonged QTc was commonly associated with TdP and was a powerful predictor of short-term mortality, surpassing the influence of comorbidities (Gibbs et al., 2019; Pickham et al., 2012). Therefore, nurses needed to be aware of evidence-based risk factors such as female sex, hypokalemia, hypomagnesemia, bradycardia, heart disease, renal or hepatic dysfunction, high drug concentrations, and rapid rate intravenous infusion of QT-prolonging drugs (Drew et al., 2004; Sandau et al., 2017). This knowledge allowed healthcare providers to estimate individual patients' risk and make more informed clinical decisions.

Scientific statements and guidelines had been published over the years, emphasizing the risk of QTc prolongation and TdP, as well as providing general recommendations for QTc interval monitoring (Drew et al., 2004; Sandau et al., 2017; Tisdale et al., 2020). These guidelines recommended implementing QTc interval monitoring for all patients before initiating high-risk drugs such as antidysrhythmics, antibiotics, antipsychotics, or other QT-prolonging medications. It was also recommended for patients with severe bradycardia, hypokalemia, hypomagnesemia, or drug overdose. Correcting the QTi for heart rate (QTc) and monitoring it

regularly were highlighted as important practices (Drew et al., 2004; Sandau et al., 2017; Tisdale et al., 2020). The AHA updated practice standards focused on documenting the QTc interval at least once per shift for patients with indications for QTc interval monitoring (Sandau et al., 2017).

Given the variability in cardiac monitoring practices among hospitals, there was no one-size-fits-all strategy recommended (Drew et al., 2010). The AHA provided expert-based recommendations to facilitate the implementation of QTc interval monitoring by all healthcare professionals responsible for cardiac monitoring. These AHA guidelines were often referenced as best practices for QTc interval monitoring, as they could effectively capture the majority of critically ill patients who developed QTc interval prolongation (Pickham et al., 2010). Overall, adherence to current practice standards for QTc interval monitoring was crucial in identifying patients at risk and implementing appropriate measures to prevent TdP and improve patient safety.

Barriers to QTc interval monitoring. Studies have shown inappropriate use of QTc interval monitoring in the acute care setting, with both under-monitoring and over-monitoring for QTc interval prolongation (Funk et al., 2010, Funk et al., 2017). Possible reasons for not monitoring QTc interval prolongation included physicians not ordering it or nurses lacking knowledge regarding factors that put patients at risk for TdP and how to use a correction formula to adjust the measured QT interval for heart rate. Additionally, nurses may perceive using a correction formula as too difficult and time-consuming. On the other hand, some nurses found it easier to obtain QTc measurements for all patients rather than considering individual indications (Funk et al., 2010).

The underutilization and overutilization of QTc interval monitoring may have reflected a lack of knowledge among nurses. Previous studies have shown that baseline comprehension of QTi/QTc was lacking among nurses, with a significant percentage unable to calculate the QTc interval or correct for the effect of heart rate (Pickham et al., 2012; Schwimer et al., 2022). This highlighted the need for education and training to enhance nurses' understanding of QTc interval monitoring.

Furthermore, the lack of established criteria for the implementation of QTc interval monitoring in many hospitals and lack of awareness regarding current policies and procedures related to QTc interval monitoring guidelines contributed to the challenges faced in practice (Barrett, 2015). The absence of a firmly established threshold below which QTc prolongation was considered free of proarrhythmic risk further complicated decision-making and monitoring practices (Sandau et al., 2017).

Addressing these barriers required a multifaceted approach. Education and training programs could improve nurses' knowledge and skills related to QTc interval monitoring. Implementing clear criteria and guidelines for when to monitor QTc intervals could help ensure appropriate utilization. Additionally, raising awareness of current policies and procedures among healthcare professionals could promote adherence to evidence-based practices. Regular updates and ongoing education could help nurses stay informed about the latest guidelines and best practices in QTc interval monitoring. By addressing these barriers, healthcare organizations could enhance the quality and safety of patient care by improving the appropriate utilization of QTc interval monitoring and reducing the associated risks of TdP.

Interventions and strategies to improve QTc interval monitoring among nurses. The mentioned studies provided valuable insights into the effectiveness of different interventions to

improve QTc interval monitoring among nurses (Funk et al., 2017; Pickham et al., 2012; Schwimer et al., 2022). The quasi-experimental study by Pickham et al. (2012) showed that QT-education classes had a positive impact on nurses' knowledge and skills related to QTc interval monitoring. Nurses who received the educational intervention showed significant improvements in correctly identifying the risk of TdP associated with QT interval prolongation, accurately marking QT and RR intervals, and calculating QTc interval (Pickham et al., 2012).

Another quality improvement study by Schwimer et al. (2022) focused on critical care units and implemented a QTc interval monitoring protocol. The study found that before the protocol implementation, QTi monitoring was inconsistent. However, after implementation of the protocol and educational intervention, nurses' knowledge, and ability to identify and monitor patients at risk for QTc interval prolongation significantly improved and were retained even after four months.

The multisite randomized trial conducted by Funk et al. (2017) explored the effects of implementing ECG monitoring practice standards. The intervention included an interactive online ECG monitoring education program and strategies to implement and sustain change in practice. The study demonstrated that nurses' knowledge significantly improved immediately following the intervention, and the intervention was associated with improvements in the quality of care, particularly in terms of appropriate monitoring.

These findings collectively highlighted the effectiveness of educational interventions, protocol implementation, and practice standard implementation in improving nurses' knowledge, skills, and adherence to QTc interval monitoring. By providing education, protocols, and ongoing support, healthcare organizations were able to enhance nurses' competency and confidence in QTc interval monitoring, leading to improved patient safety and outcomes. It is

important to note that a comprehensive approach, combining education, protocols, and ongoing evaluation, was essential for sustaining the improvement and ensuring the integration of evidence-based practice standards into daily clinical practice.

Summary of Evidence

Collaboration across the different multidisciplinary teams and the implementation of structured nurse education programs and strategies had been shown to be effective in improving QTc interval monitoring among nurses (Funk et al., 2017; Pickham et al., 2012; Schwimer et al., 2022). By identifying barriers to QTc interval monitoring, educational tools were developed to enhance nurses' knowledge and skills in identifying and monitoring patients at risk for QTc prolongation and TdP (Funk et al., 2010). These studies provided evidence of the efficacy of educational interventions in improving QTc interval monitoring practices among nurses in healthcare settings.

Strength of evidence. The strength of this literature search could be described as moderate. The quality of evidence varied, with a majority of the articles falling under the level VII in Mosby's grading system, which relied on expert opinions. While these expert opinions drove the practice standards for QTc interval monitoring, they may have been subject to bias and errors of reasoning. High-quality meta-analyses and randomized controlled trials specifically focusing on educating nurses on best practice standards for QTc interval monitoring were difficult to find.

The quantity of available literature was fair, although it was necessary to extend the search beyond the past 10 years to include research conducted in the past 20 years to gather sufficient information. While there was enough existing research to provide an adequate

understanding of the topic, studies with large sample sizes and robust research designs were limited.

Consistency in the findings was observed across the themes of current practice standards for QTc interval monitoring and barriers to QTc interval monitoring. Despite variations in study design and sample sizes, the results were largely in agreement. However, the literature on strategies and interventions to improve QTc interval monitoring among nurses was relatively limited. Nevertheless, the available findings were largely aligned across studies.

Overall, while the evidence provided valuable insights and supported certain conclusions, it is important to recognize the limitations and consider the moderate strength of the evidence base in this area of research.

Gaps in knowledge and limitations of evidence. The literature review identified several gaps in knowledge and limitations of the evidence regarding strategies and interventions to improve QTc interval monitoring among nurses. Firstly, there was a limited number of robust studies that focused specifically on interventions to improve nurses' QTc interval monitoring. While some studies demonstrated the effectiveness of educational programs, more research was needed to explore other potential interventions and evaluate their impact on nurses' knowledge and practice.

Secondly, the evidence on current practice standards for QTc interval monitoring was also limited. Most published articles were scientific statements written by experts over a span of 20 years, indicating a lack of recent in-depth understanding of current practices and guidelines. The absence of meta-analyses detailing utilization rates and adherence to practice standards further emphasized the need for more comprehensive research in this area.

To address these gaps in knowledge and limitations of the evidence, further research was needed to develop and evaluate educational interventions specifically tailored to improving QTc interval monitoring among nurses. Additionally, more studies should be conducted to assess the utilization rates and adherence to current practice standards, providing a clearer understanding on the implementation and effectiveness of these guidelines in real-world clinical settings.

Overall, these gaps and limitations highlighted the need for additional research to enhance the evidence base and inform the development of effective strategies and interventions for improving QTc interval monitoring among nurses.

Methods

Project Design

This quality improvement project conducted in conjunction with the University of Hawai'i at Manoa and QMC - Punchbowl Campus translated current AHA practice standards on QTc interval monitoring into an evidence-based educational initiative for telemetry nurses. By developing an educational presentation on QTc interval monitoring, the goal of this project was to improve nurses' knowledge and self-efficacy in QTc interval monitoring.

This project did not require IRB approval by the University of Hawai'i or QMC as all the project initiatives aimed for evidence-based practice change and quality improvement. A memorandum by the University of Hawai'i Office of Research Adherence states, "the DNP quality improvement project required by the UH School of Nursing is not considered human subjects research" (Appendix C). The author of the project completed Collaborative Institutional Training Initiative (CITI) training for research ethics and adherence, as well as Health Insurance Portability and Accountability Act (HIPAA) training on patient privacy protections.

All student projects conducted at any location of The Queen's Health System must obtain approval from the QMC Research & Institutional Review Committee (RIRC) prior to implementation. Through QMC internal IRB process, the author obtained a QMC RIRC letter of confirmation (Appendix D).

Setting

The quality improvement project was implemented on a telemetry unit (Pauahi 5) at the QMC - Punchbowl campus. QMC was the first and only hospital in Hawaii to achieve Magnet Recognition from the American Nurses Credentialing Center. This recognition acknowledged excellence in nursing and quality patient outcomes, highlighting QMC's commitment to quality and patient safety.

Pauahi 5 was a 30-bed telemetry unit with semi-private rooms that operate on a 24-hour basis. The unit primarily cared for patients with diagnoses such as congestive heart failure, pneumonia, syncope, arrhythmias, and electrolyte abnormalities. Many of the patients on the unit had complex medical comorbidities. The patients cared for on the unit included adults between the ages of 18 and 64, as well as, and geriatric patients who are 65 years old and above.

Participants

The eligible participants for this project were telemetry nurses working at QMC - Punchbowl Campus on Pauahi 5. Nurses were recruited through text messages and emails sent to the staff list (Appendix E). Permission to engage with these nurses was granted by the unit manager, Sarah Williams.

Intervention

To align QMC telemetry nurses with current national AHA practice standards on QTc interval monitoring, an evidence-based QT educational presentation was developed as an

intervention. This presentation focused on enhancing knowledge and assessment of QTc interval monitoring and TdP. It was created with the guidance of key clinical experts. The educational intervention consisted of three parts: pre-presentation knowledge and self-efficacy questions, an evidence-based QT educational PowerPoint presentation recording, and post-presentation knowledge and self-efficacy questions.

Prior to reviewing the evidence-based QT educational PowerPoint presentation, nurses completed the QT Knowledge and Self-Efficacy Test (pretest). This allowed nurses to self-evaluate their knowledge and self-efficacy in caring for patients who require QTc interval monitoring, while also providing a baseline measure of their QT-monitoring ability. Following the pretest, participants watched a recorded QT educational PowerPoint presentation that was based on the AHA practice standards for QTc interval monitoring. The presentation covered key concepts including:

1. The clinical relevance of QTc interval prolongation and TdP.
2. Characteristic patterns and ECG signs of TdP.
3. General risk factors for TdP in hospital settings.
4. Common medications that may prolong the QTc interval and/or cause TdP.
5. Definition of prolonged QTc interval.
6. An overview of QTc interval monitoring.

After viewing the educational presentation (Appendix F), nurses completed the QT Knowledge and Self-Efficacy a second time (post-test). This allowed the assessment of knowledge and self-efficacy improvement following the educational intervention.

Data Collection

Protocol and procedures: This quality improvement project method included a pre-posttest design with an educational intervention. To recruit participants, the author sent emails using the Dillman Method (Hodinott & Bass, 1986) over a period of three weeks. Three emails were sent to potential participants. The first email introduced the project and invited people to participate. The second email was sent one week later as a follow-up, reiterating the invitation to participate. Finally, a third email was sent one week later as a final reminder for potential participants. In total, potential participants had three weeks to participate in this quality improvement project.

Measures: All data collected in this project was non-identifiable and collected anonymously. Demographic information was gathered from each participant, including the number of years licensed as a registered nurse and years working as a telemetry nurse. To ensure privacy and minimize the collection of data that could identify the individuals, age, gender, and race were not collected due to small sample sizes.

Two assessment tools were utilized in this project. The first tool utilized was the pre- and post-intervention knowledge test to measure participants' knowledge gain after viewing the evidence-based QT educational PowerPoint presentation. The knowledge test consisted of 12 fixed-response questions (Appendix G). These questions were adapted from a 2012 study and the 2010 joint scientific statement from the AHA and the ACCF for the prevention of TdP (Drew et al., 2010; Pickham et al., 2012). Expert consultation was used to validate this instrument. Each correct response was given a value of 1, with a maximum achievable score of 12. A higher score indicated a greater knowledge gain from the educational presentation.

The second tool utilized was the pre- and post-intervention self-efficacy item questionnaire. This questionnaire aimed to measure participants' self-efficacy with QTc interval monitoring and TdP after viewing the evidence-based QT educational PowerPoint presentation. The self-efficacy items were based on the concept derived from the health belief model (Rosenstock, Strecher, & Becker, 1988) and utilized 5-point Likert scales. Participants responded to 6 statements related to QTc interval monitoring and TdP, with response options ranging from 1 to 5 (Appendix H). A score of "1" indicated "Not at all confident," while "5" indicated "Completely confident." Individual participants' scores were added, resulting in a range of 6 to 30. A higher score indicated an increased confidence in one's ability to perform QTc interval monitoring. The self-efficacy measures covered areas such as identifying patients who require QTc interval monitoring, accurately performing QTc interval monitoring, notifying the physician of prolonged QTc intervals, recognizing risk factors for TdP, recognizing early ECG warning signs of TdP, and identifying TdP on a telemetry monitor.

Data Analysis

The quantitative data collected in this project was analyzed using descriptive statistics, including mean for continuous variables and percentages for nominal data. To manage and analyze the data, Microsoft Excel spreadsheets and aggregate data tables were utilized. The pre-post test data from the knowledge test and self-efficacy questionnaire were entered into the spreadsheet for analysis. Comparisons were made between pre- and post-intervention data to assess for any changes.

Results

Demographics of the Participants

Out of 54 registered nurses on Pauahi 5, a total of 22 nurses participated in the pre-intervention group. Among the 22 nurses, 17 participated in the intervention and completed both the pretest and posttest. The participation rates in the pre- and post-test intervention groups were 40.74% and 31.48%, respectively. The characteristics of the nurses in the pre-intervention and post-intervention groups are described in Table 2.

Table 2. Nurse-Related Participant Characteristics

Characteristics of participants	**Pre-Intervention (n=22)**	**Post-Intervention (n=17)**
Years licensed as a registered nurse	n (%)	n (%)
Less than 2 years	3 (13.6)	3 (17.6)
2-5 years	4 (18.2)	4 (23.5)
6-10 years	4 (18.2)	3 (17.6)
11-20 years	8 (36.4)	4 (23.5)
21-30 years	3 (13.6)	3 (17.6)
Years working as a telemetry nurse		
Less than 2 years	3 (13.6)	3 (17.6)
2-5 years	5 (22.7)	5 (29.4)
6-10 years	5 (22.7)	4 (23.5)
11-20 years	8 (36.4)	4 (23.5)
21-30 years	1 (4.5)	1 (5.9)

Quantitative Results

QT Knowledge Test

In the pre-intervention group, the mean score on the QT knowledge test was 8.23 out of 12.00. A higher score indicates a higher baseline knowledge on QTc interval monitoring and TdP. Scores could range from 0 to 12. Nurses with 6-10 years of nursing and telemetry experience had the highest mean pre-intervention scores (9.00/12.00; 9.20/12.00), while nurses with less than two years of nursing and telemetry experience had the lowest scores (6.33/12.00).

In the post-intervention group, the mean score on the QT knowledge test was 9.65 out of 12.00. The overall mean score on the posttest increased for all participants. Nurses with 11-20 years of nursing and telemetry experience had the highest scores in the post-intervention group (10.75/12.00; 10.25/12.00), but those with less than two years of nursing and telemetry experience showed the greatest increase in knowledge test scores (6.33/12.00 to 9.33/12.00). Table 3 displays the mean knowledge test scores for all participants as well as the mean scores for each subgroup in both the pre- and post-intervention groups.

Table 3. Participant Characteristics and Pre- and Post-Intervention Mean Knowledge Test Scores

Characteristics of participants	**Pre-Intervention (n=22)**	**Post-Intervention (n=17)**
	Mean Score (Out of 12.00)	Mean Score (Out of 12.00)
All participants	8.23	9.65
Years licensed as a registered nurse		
Less than 2 years	6.33	9.33
2-5 years	7.25	9.25
6-10 years	9.00	8.67
11-20 years	8.88	10.75
21-30 years	8.67	10.00
Years working as a telemetry nurse		
Less than 2 years	6.33	9.33
2-5 years	7.80	9.60
6-10 years	9.20	9.25
11-20 years	8.63	10.25
21-30 years	8.00	10.00

Note. QT knowledge test consisted of 12 fixed-response questions. Each correct response was given a value of 1, with a maximum achievable score of 12.

Item Wise QT Knowledge Test Questions

In the pre-intervention group, nurses scored the highest on the QT knowledge test questions related to understanding QTc interval monitoring recommendations and risk factors for QT prolongation. They scored lowest on questions related to risk factors for TdP, QTc interval

monitoring indications, and characteristic ECG signs of TdP. Detailed responses to the knowledge test questions are provided in Table 4.

In the post-intervention group, there was an increase in knowledge test scores for every question item, except for items 7 and 8. Nurses demonstrated the greatest improvement in knowledge for questions related to characteristics ECG signs of TdP, ECG signs of impending TdP, QT-prolonging medications, and QTc interval monitoring indications. The posttest knowledge responses are outlined in Table 4.

Table 4. Proportion of Correct Responses per QT Knowledge Test Question Item

Question	**% of correct responses[a]**	
	Pre-Intervention (n=22)	**Post-Intervention (n=17)**
1. The ECG shows TdP	59.09	70.59
2. QT-interval prolongation increases the risk for TdP	86.36	100.00
3. Congenital long QT syndrome, hypokalemia, hypomagnesemia, and bradycardia can cause QT prolongation	90.91	100.00
4. The QT interval should be monitored at least once per 8 hours	100.00	100.00
5. QT interval correction adjusts for heart rate providing the QTc interval	72.73	94.12
6. A patient with a drug overdose is a priority for QT-interval monitoring	54.55	76.47
7. Bundle-branch block causes depolarizing-type prolongation of the QT interval	72.73	47.06
8. Risk for TdP is greatest with ibutilide after return to sinus rhythm (long pause)	36.36	29.41
9. Pantoprazole has no known risk for TdP	68.18	94.12
10. A QTc value > 500 ms should prompt a critical reevaluation of drug therapy	59.09	76.47
11. Of the choices provided, a short PR interval and a delta wave is not characteristic sign of TdP	59.09	88.24
12. Of the choices provided, monomorphic VT is least likely a sign for TdP	63.64	88.24

Abbreviations: TdP, torsade de pointes; QT, QT interval; QTc, corrected QT interval; VT, ventricular tachycardia.

Note. [a]Difference between percentage of correct responses before and after educational intervention for all QT knowledge test questions.

QT Self-efficacy Questionnaire

In the pre-intervention group, the mean score on the QT self-efficacy questionnaire was 18.27 out of 30.00. A higher score indicates a higher perceived self-efficacy in QTc interval monitoring and TdP. Scores could range from 6 to 30. Nurses with 6-10 and 11-20 years of nursing experience and 21-30 years of telemetry experience had the highest pre-intervention self-efficacy scores, while those with less than two years of nursing and telemetry experience had the lowest scores.

In the post-intervention group, the mean score on the QT self-efficacy questionnaire was 23.47 out of 30.00. The overall mean score on the posttest increased for all participants. Nurses with 11-20 years of nursing experience and 21-30 years of telemetry experience had the highest scores in the post-intervention group, but those with less than two years of nursing and telemetry experience showed the greatest increase in self-efficacy scores. Table 5 displays the mean self-efficacy scores for all participants as well as the mean scores for each subgroup in both the pre- and post-intervention groups.

Table 5. Participant Characteristics and Pre-and Post-intervention Mean Self-efficacy Scores

Characteristics of participants	**Pre-Intervention (n=22)**	**Post-Intervention (n=17)**
	Mean Score (Out of 30.00)	Mean Score (Out of 30.00)
All participants	18.27	23.47
Years licensed as a registered nurse		
Less than 2 years	13.67	23.33
2-5 years	16.25	23.50
6-10 years	19.75	22.67
11-20 years	19.75	24.25
21-30 years	19.67	23.33
Years working as a telemetry nurse		
Less than 2 years	13.67	23.33
2-5 years	16.40	23.60
6-10 years	19.80	23.00

11-20 years	19.88	22.75
21-30 years	21.00	28.00

Note. QT self-efficacy questionnaire consisted of 6 Likert scale statements, with response options ranging from 1 to 5. The minimum mean score was 6 and the maximum mean score was 30.

Item Wise QT Self-efficacy Questionnaire

In the pre-intervention group, nurses scored the highest on self-efficacy question items related to recognizing TdP on the telemetry monitor and notifying the MD about prolonged QTc intervals. They scored the lowest on question items related to recognizing the early ECG warning signs of TdP, recognizing the risk factors for TdP, and identifying patients who require QTc interval monitoring. Detailed responses to the self-efficacy questions are provided in Table 6.

In the post-intervention group, there was an increase in self-efficacy scores for every question item. Nurses showed the greatest improvement in perceived self-efficacy for question items related to recognizing the early ECG warning signs of TdP, recognizing the risk factors for TdP, and identifying patients who require QTc interval monitoring. The areas that ranked lowest in the pre-intervention group demonstrated the greatest improvement in self-efficacy scores. The post-test self-efficacy scores are outlined in Table 6.

Table 6. Mean Self-efficacy Score per QT Self-efficacy Question Item

Question	**Self-efficacy Score[a]**	
	Pre-Intervention (n=22)	**Post-Intervention (n=17)**
	Mean Score (Out of 5.00)	Mean Score (Out of 5.00)
1. Identifying patients who require QTc interval monitoring	2.77	3.71
2. Accurately performing QTc interval monitoring	3.05	3.88
3. Notifying MD of prolonged QTc intervals	3.32	3.94
4. Recognizing the risk factors for TdP	2.82	3.76
5. Recognizing the early ECG warning signs of TdP	2.55	3.82
6. Recognizing TdP on a telemetry monitor	3.77	4.35

Abbreviations: QTc, corrected QT interval; MD, Doctor of Medicine; TdP, torsade de pointes; ECG, electrocardiogram.
Note. [a]Difference between mean self-efficacy scores before and after educational intervention for all QT self-efficacy questions. The lowest mean self-efficacy score was 1 and the highest mean self-efficacy score was 5.

Discussion

This quality improvement project aimed to increase both nurses' knowledge and self-efficacy with QTc interval monitoring and TdP through the implementation of an evidence-based QT educational presentation based on AHA practice standards for QTc interval monitoring. Our findings showed an improvement in nursing knowledge and self-efficacy, according to the results of the knowledge assessment and self-efficacy assessment administered before and after the intervention. This quality improvement initiative effectively engaged nurses, utilizing best-practice recommendations and evidence-based education, to improve practice related to QTc interval monitoring and TdP.

At baseline, nurses who participated had a poor level of proficiency with QTc interval monitoring and TdP, as suggested as a likely finding by previous studies (Pickham et al., 2012; Schwimer et al., 2022). Participants' knowledge improved after the educational intervention, with an overall average of 68.58% correct responses to knowledge assessment questions at baseline and 80.42% immediately after education. Similarly, participants' self-efficacy improved after the educational intervention, with an overall average score of 18.27 on a 30-point scale at baseline and 23.47 on a 30-point scale immediately after the intervention. The results of this project aligned with the literature which explicates that educational interventions are likely to improve nurses' knowledge of QTc interval monitoring and TdP, as well as enhance nurses' competency and confidence in QTc interval monitoring.

Interestingly, participants with less than 5 years of practice had the greatest improvement in knowledge and self-efficacy scores. Following education, participants with less than 2 years of experience on a telemetry unit had a 25% increase in knowledge scores and a 32.20% increase in self-efficacy scores. Similarly, participants with 2 to 5 years of experience as a nurse had a 16.66% increase in knowledge scores and a 24.16% increase in self-efficacy scores. Participants with 2 to 5 years of experience in telemetry had a 15% increase in knowledge scores and a 24% increase in self-efficacy scores. The findings suggest that educational interventions may be effective and that new nurses and nurses new to telemetry care should be prioritized for ongoing educational interventions. Hallaran, Edge, Almost, and Tregunno's (2023) thematic analysis of the barriers to transition to practice for new nurses include reported lack of confidence and unmet clinical learning needs. Clearly, support is needed for continuing education strategies to address reported lack of confidence and unmet clinical learning needs among new nurses to the profession as well as nurses transitioning from one specialty to another.

In the post-intervention assessment, participants' QT knowledge improved on all questions items, expect for two: the first item being that bundle-branch block causes depolarizing-type prolongation of the QT interval, and the second item being that the risk for TdP is greatest with ibutilide after return to sinus rhythm (long pause). Though not directly clear how participants had a drop in knowledge for these two questions, this finding reflected either 1) poorly written questions or 2) the educational intervention created confusion or did not address the item material in a comprehensible way. Consequently, future work should re-examine these items and adaptions should be made to the test questions and the interventional materials.

The results have implications for clinical practice. Within the healthcare environment, nurses are uniquely situated to provide QTc interval monitoring. Careful ECG monitoring is

crucial to identifying declining or decompensating conditions that may progress to life-threatening sustained arrythmia. Hospitals with the lowest incidence of cardiac arrest also are known to have the greatest arrest survival rate (Sandau et al., 2017). Although this finding likely had many contributing factors, early recognition of at-risk patients likely improved the overall mortality rate. Previous studies have shown that baseline comprehension of the QT interval was lacking among nurses. Pickham et al. (2012), Funk et al. (2017), and Schwimer et al. (2022) all documented that knowledge test scores improved following an educational intervention. This project demonstrated similar results, with participants' knowledge improving after an educational intervention.

Limitations

This quality improvement project had four main limitations. First, there was a lack of retention between pre- and post-intervention groups. Five participants did not participate in the posttest. Therefore, the results for knowledge and self-efficacy may have been skewed. Second, the project had a small sample size and utilized a purposive, convenience sample instead of a larger, diverse, and random sample. Previous reports have documented important barriers to nurses' ability to participate in continuing education, and these include time constraints and work commitments (Shahhosseini & Hamzehgardeshi, 2015). Third, this quality improvement project was conducted with a sample of nurses from one institution. The abilities of nurses within this sample may not reflect those of nurses elsewhere. Since this sample primarily consisted of experienced nurses (68% with >5 years' experience in the pre-intervention group and 59% with >5 years' experience in the post-intervention group), the results may have overestimated the knowledge and self-efficacy of other nurses regarding QTc interval monitoring and TdP. Fourth,

this project was limited by time. A long-term follow up was not possible to assess retained knowledge and self-efficacy over time.

Implications for Nursing Practice/Future Developments

Knowledgeable and highly skilled nurses play a vital role in the care of hospitalized patients. This quality improvement project supports the notion that self-efficacy and nursing knowledge could be improved, particularly among new nurses and nurses new to a specialty, through an educational intervention focused on QTc interval monitoring and TdP. It also highlights the clear necessity for ongoing education among all nursing staff, no matter their tenure. To meet the expected level of practice and professional performance, improvements are required to further develop the educational intervention beyond the initial pilot phase. Additionally, there is a need for further research to determine the most effective educational interventions for nurses in different clinical settings, as the impact of various educational intervention strategies on QTc interval monitoring and TdP have not been extensively studied. Conducting additional research on the facilitators and barriers to providing QTc interval monitoring and TdP to newer nurses would be valuable in shaping future evidence-based quality improvement endeavors aimed at enhancing knowledge and self-efficacy among new and less experienced nurses.

Conclusion

This quality improvement project highlighted that the participants exhibited a low level of knowledge (68.58%) and self-efficacy (18.27 on a 30-point scale) regarding QTc interval monitoring and TdP during the pre-intervention assessment. After implementation of an educational intervention, this quality improvement project successfully increased participants'

scores on QT self-efficacy posttest assessment as well as on the QT knowledge posttest. However, it also highlighted that there remained room for continued improvement.

The project findings demonstrated that relying solely on education was insufficient when implementing the AHA practice standards for QT interval monitoring and TdP. To address this issue, future interventions should include a comprehensive approach for telemetry nurses, which involves a combination of education, protocol reinforcement, and ongoing long-term evaluation. This approach would aim to enhance and ensure the integration of evidence-based practice standards into daily clinical practice.

Continuing education for QTc interval monitoring and TdP is crucial in promoting best-practice standards and patient safety. Therefore, it is imperative to prioritize ongoing educational interventions as a significant aspect of ECG monitoring in a telemetry acute care setting. By upholding this commitment to education, healthcare professionals can maintain high-quality standards and enhance patient care.

References

Barrett, T. (2015). Why are we prolonging QT interval monitoring?. *Dimensions of Critical Care Nursing*, *34*(3), 130-133. doi:10.1097/DCC.0000000000000110

Drew, B. J., Califf, R. M., Funk, M., Kaufman, E. S., Krucoff, M. W., Laks, M. M., … Van Hare, G. F. (2004). Practice standards for electrocardiographic monitoring in hospital settings: An american heart association scientific statement from the councils on cardiovascular nursing, clinical cardiology, and cardiovascular disease in the young: Endorsed by the international society of computerized electrocardiology and the american association of critical-care nurses. *Circulation*, *110*(17), 2721–2746. doi:10.1161/01.CIR.0000145144.56673.59

Drew, B. J., Ackerman, M. J., Funk, M., Gibler, W. B., Kligfield, P., Menon, V., … Zareba, W. (2010). Prevention of torsade de pointes in hospital settings. *Journal of the American College of Cardiology*, *55*(9), 934–947. doi:10.1016/j.jacc.2010.01.001

Funk, M., Winkler, C. G., May, J. L., Stephens, K., Fennie, K. P., Rose, L. L., … Drew, B. J. (2010). Unnecessary arrhythmia monitoring and underutilization of ischemia and qt interval monitoring in current clinical practice: Baseline results of the practical use of the latest standards for electrocardiography trial. *Journal of Electrocardiology*, *43*(6), 542–547. doi:10.1016/j.jelectrocard.2010.07.018

Funk, M., Fennie, K. P., Stephens, K. E., May, J. L., Winkler, C. G., Drew, B. J., … White, P. (2017). Association of implementation of practice standards for electrocardiographic monitoring with nurses' knowledge, quality of care, and patient outcomes: Findings from the practical use of the latest standards of electrocardiography (pulse) trial. *Circulation:*

Cardiovascular Quality and Outcomes, *10*(2), e003132. doi:10.1161/CIRCOUTCOMES.116.003132

Gibbs, C., Thalamus, J., Kristoffersen, D. T., Svendsen, M. V., Holla, Ø. L., Heldal, K., … Hysing, J. (2019). QT prolongation predicts short-term mortality independent of comorbidity. *EP Europace*, *21*(8), 1254–1260. doi:10.1093/europace/euz058

Hallaran, A. J., Edge, D. S., Almost, J., & Tregunno, D. (2023). New nurses' perceptions on transition to practice: A thematic analysis. *Canadian Journal of Nursing Research*, *55*(1), 126-136. doi:10.1177/08445621221074872

Hoddinott, S. N., & Bass, M. J. (1986). The dillman total design survey method. *Canadian family physician Medecin de famille canadien*, *32*, 2366–2368.

Iowa Model Collaborative, Buckwalter, K. C., Cullen, L., Hanrahan, K., Kleiber, C., McCarthy, A. M., … Tucker, S. (2017). Iowa model of evidence-based practice: Revisions and validation: Iowa model-revised. *Worldviews on Evidence-Based Nursing*, *14*(3), 175–182. doi:10.1111/wvn.12223

Pickham, D., Helfenbein, E., Shinn, J. A., Chan, G., Funk, M., & Drew, B. J. (2010). How many patients need qt interval monitoring in critical care units? Preliminary report of the qt in practice study. *Journal of Electrocardiology*, *43*(6), 572–576. doi: 10.1016/j.jelectrocard.2010.05.016

Pickham, D., Helfenbein, E., Shinn, J. A., Chan, G., Funk, M., Weinacker, A., … Drew, B. J. (2012). High prevalence of corrected qt interval prolongation in acutely ill patients is associated with mortality: Results of the qt in practice (qtip) study*. *Critical Care Medicine*, *40*(2), 394–399. doi:10.1097/CCM.0b013e318232db4a

Pickham, D., Shinn, J. A., Chan, G. K., Funk, M., & Drew, B. J. (2012). Quasi-experimental

study to improve nurses' qt-interval monitoring: Results of qtip study. *American Journal of Critical Care, 21*(3), 195–200. doi:10.4037/ajcc2012245

Rosenstock, I. M., Strecher, V. J., & Becker, M. H. (1988). Social learning theory and the health belief model. *Health Education Quarterly*, *15*(2), 175–183. doi:10.1177/109019818801500203

Sandau, K. E., Funk, M., Auerbach, A., Barsness, G. W., Blum, K., Cvach, M., … Wang, P. J. (2017). Update to practice standards for electrocardiographic monitoring in hospital settings: A scientific statement from the american heart association. *Circulation, 136*(19). doi:10.1161/CIR.0000000000000527

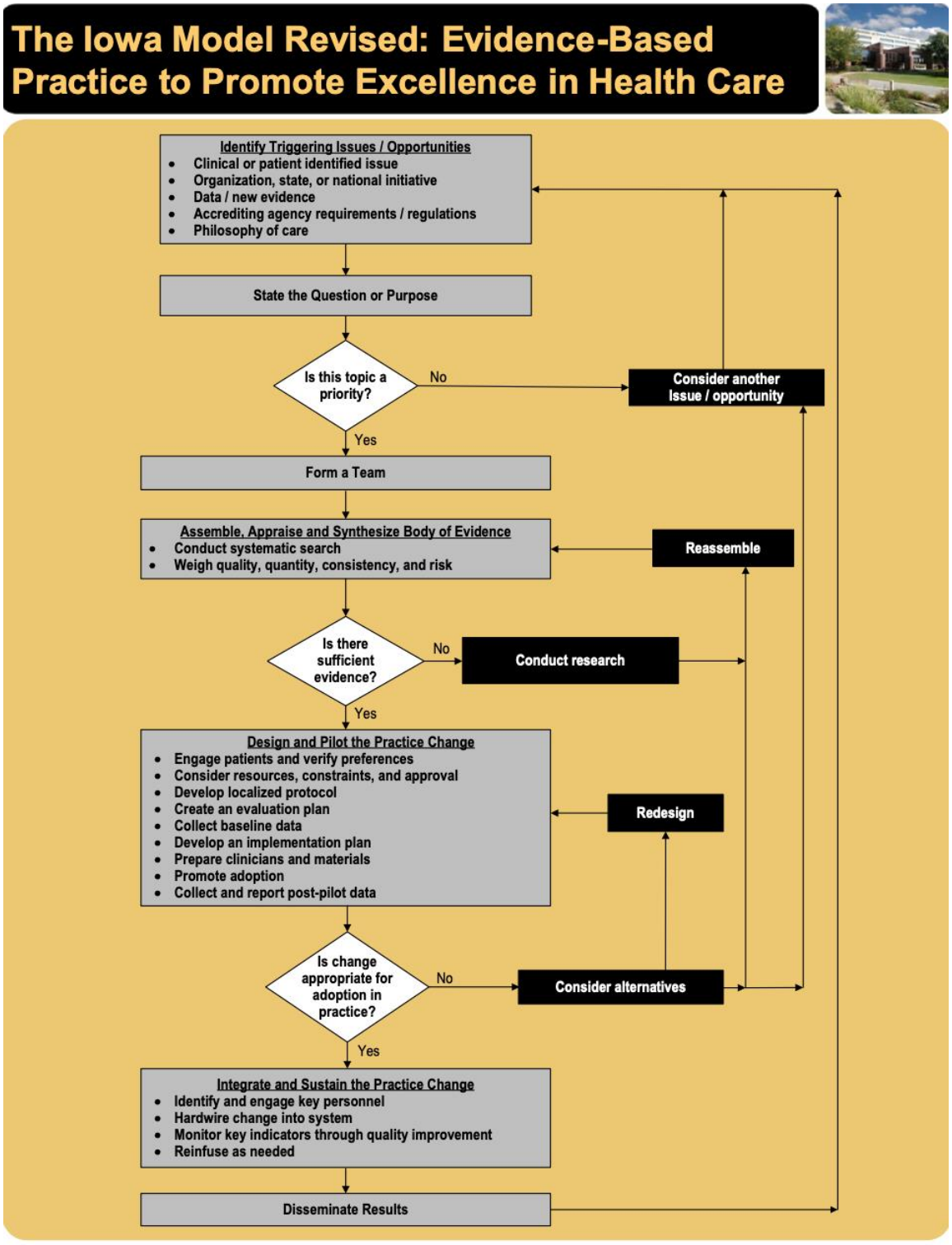
Schwimer, D., Al-Zaiti, S., & Beach, M. (2022). Improving corrected qt interval monitoring in critical care units: A single center report. *Critical Care Nurse*, *42*(1), 33–43. doi:10.4037/ccn2022465

Shahhosseini, Z., & Hamzehgardeshi, Z. (2015). The facilitators and barriers to nurses' participation in continuing education programs: A mixed method explanatory sequential study. *Global journal of health science, 7*(3), 184. doi:10.5539/gjhs.v7n3p184

Tisdale, J. E., Chung, M. K., Campbell, K. B., Hammadah, M., Joglar, J. A., Leclerc, J., … On behalf of the American Heart Association Clinical Pharmacology Committee of the Council on Clinical Cardiology and Council on Cardiovascular and Stroke Nursing. (2020). Drug-induced arrhythmias: A scientific statement from the american heart association. *Circulation, 142*(15). doi:10.1161/CIR.0000000000000905

Trinkley, K. E., Lee Page, R., Lien, H., Yamanouye, K., & Tisdale, J. E. (2013). Qt interval prolongation and the risk of torsades de pointes: Essentials for clinicians. *Current Medical Research and Opinion, 29*(12), 1719–1726. doi:10.1185/03007995.2013.840568

Appendix A


The Iowa Model Revised: Evidence-Based Practice to Promote Excellence in Health Care
Identify Triggering Issues / Opportunities
Clinical or patient identified issue
Organization, state, or national initiative
Data / new evidence
Accrediting agency requirements / regulations
Philosophy of care
State the Question or Purpose
Is this topic a priority?
No
Consider another Issue / opportunity
Yes
Form a Team
Assemble, Appraise and Synthesize Body of Evidence
Conduct systematic search
Weigh quality, quantity, consistency, and risk
Reassemble
Is there sufficient evidence?
No
Conduct research
Yes
Design and Pilot the Practice Change
Engage patients and verify preferences
Consider resources, constraints, and approval
Develop localized protocol
Create an evaluation plan
Collect baseline data
Develop an implementation plan
Prepare clinicians and materials
Promote adoption
Collect and report post-pilot data
Redesign
Is change appropriate for adoption in practice?
No
Consider alternatives
Yes
Integrate and Sustain the Practice Change
Identify and engage key personnel
Hardwire change into system
Monitor key indicators through quality improvement
Reinfuse as needed
Disseminate Results

Appendix B

Literature Review Summary Table

Author/Date	Focus/Purpose	Stated Method	Sample Description	Main Findings
Barrett, 2015	Current Practice Standards for QTc interval monitoring	Literature review; Hospital survey	• 6 bibliographic databases: CINAHL, EBSCOhost, Medline, PubMed, Google Scholar, and the Cochrane Scholar (years 2013-20214). • 4 major hospitals in the Memphis area	• Database search established the existence of published guidelines that support the needs for QTi monitoring • Hospital survey indicates direct care nurses were not aware of the need to identify high-risk patients, drugs with the potential to prolong QTi that were being administered to their patients, or evidence-based standards for QTi monitoring
Drew et al., 2004	Current Practice Standards for QTc interval monitoring	Scientific Statement	• Experts from the American Health Association's Councils on Cardiovascular Nursing, Clinical Cardiology, and Cardiovascular Disease in the Young and the International Society of Computerized Electrocardiography	• First attempt to address all the aspects of hospital ECG monitoring (cardiac arrhythmias, ischemia, and QT interval), incl. indications for monitoring and practical considerations for correct and effective monitoring
Drew et al., 2010	Current Practice Standards for QTc interval monitoring	Scientific Statement	• Experts from the American Health Association and the American College of Cardiology Foundation	• Drugs a/w TdP vary greatly in their risk of arrythmia • Risk factors for drug-induced TdP include older age, female sex, heart disease, electrolyte disorders, renal or hepatic dysfunction, bradycardia or rhythms with long pauses, treatment with more than 1 QT-prolonging drug, and genetic predisposition • The risk-benefit ratio should be assessed for everyone to determine whether the potential therapeutic benefit of a drug outweighs the risk for TdP • After initiation of a drug a/w TdP, ECG signs indicative of risk for arrhythmia include an increase in QTc from predrug baseline of 60ms, marked OTc interval prolongation >500ms, etc. • In monitoring QT intervals in an individual before and after drug administration, a consistent method should be used
Funk et al., 2010	Barriers to QTc interval monitoring	Multi-site randomized controlled trial	• 1816 patients in 17 hospitals across the United States	• Almost all (99%) patients with an indication for arrhythmia monitoring were being monitored, but 85% of patients with no indication were monitored • Only 21% of patients with an indication for QT interval monitoring had a QTc documented, but 18% of patients with no indication had a QTc documented
Funk et al., 2017	Barriers to QTc interval monitoring; Interventions and strategies to improve QTc interval monitoring among nurses	Multi-site randomized controlled trial	• 65 cardiac units in 17 hospitals across the United States • Total of 3,013 nurses, 4,587 patients, and 95,884 hospital admissions	• Combination of online ECG monitoring education and strategies to implement and sustain change in practice was effective • Nurses' knowledge, measures of quality of care (i.e., appropriate monitoring), and the outcome of in-hospital MI improved significantly following the intervention, but only improvement in nurses' knowledge was not sustained 15 months after the intervention

Gibbs et al., 2019	Current Practice Standards for QTc interval monitoring	Retrospective cohort study	• 980 patients with QTc >/=500 ms who were hospitalized at Telemark Hospital Trust, Norway and 980 patients with QTc <500 ms, matched for age and sex and adjusting for Charlson comorbidity index (CCI), previous admissions, and main diagnoses	• QTc >/= a/w increased 30-day all-cause mortality • QTc >/= 500ms is a powerful predictor of short-term mortality overruling comorbidities
Pickham et al., 2010	Current Practice Standards for QTc interval monitoring	Prospective observational study	• QT data from bedside monitors of all patients (N=1039) admitted to one of five critical care units providing continuous QTi monitoring (154 beds) at Stanford University Medical Center over a 2-month period • Units included in the study were: Cardiovascular ICU, Medical/Surgery/Trauma ICU, Coronary Care Unit, Cardiovascular Progressive Care Unit, and the Medical/Surgery/Trauma Progressive Care Unit	• 69% of patients has 1 or more AHA indications for QTi monitoring • More women (74%) had indications than men (64%) • One quarter (24%) had QTi prolongation (QTi >500 ms for ≥15 minutes) • Odds for QTi prolongation increased with the number of AHA indications present • Positive predictive value of the AHA indications for QTi prolongation were 31.2%; negative predicative value was 91.3%
Pickham et al., 2012	Current Practice Standards for QTc interval monitoring	Prospective observational study	• QT data from bedside monitors of all patients (N=1039) admitted to one of six critical care units providing continuous QT monitoring (154 beds) at Stanford University Medical Center over a 2-month period • Patients admitted included acutely ill medical, surgical, trauma, neurosurgical, vascular surgery, and cardiothoracic patients	• QT prolongation (QTc >/= 500ms) is common (24%) with TdP representing 6% of in-hospital cardiac arrests • Acutely ill patients with QT prolongation have longer lengths of hospitalization and nearly three times the odds for mortality than those without QT prolongation
Pickham et al., 2012	Barriers to QTc interval monitoring; Interventions and strategies to improve QTc interval monitoring among nurses	Quasi-experimental study	• 480 nurses on an adult inpatient unit providing continuous cardiac monitoring (intensive/progressive care units) at a large academic medical center located on the West Coast of the United States	• 94% of nurses were unable to calculate the QTc interval at baseline • QT-related educational class significantly improved nurses' ability to provide QTi monitoring, but nearly half of all nurses were still unable to calculate the OTc interval

Sandau et al., 2017	Current Practice Standards for QTc interval monitoring	Scientific Statement	• Experts commissioned by American Heart Association from general cardiology, electrophysiology (adult and pediatric), interventional cardiology, as well as a hospitalist and experts in alarm management	• In response to the new issues that emerged from the original practice standards (published in 2004) which incl: overuse of arrhythmia monitoring among a variety of patient populations, appropriate use of ischemia and QTi monitoring among select population, alarm management, and documentation in electronic health records • Document is grouped into 5 sections: 1) Overview of Arrhythmia, Ischemia, and QTc Monitoring, 2) Recommendation for Indication and Duration of Electrocardiographic Monitoring presented by patient population, 3) Organizational Aspects: Alarm Management, Education of Staff, and Documentation; 4) Implementation of Practice Standards; and 5) Call for Research
Schwimer, Al-Zaiti, & Beach, 2022	Barriers to QTc interval monitoring; Interventions and strategies to improve QTc interval monitoring among nurses	Quality improvement initiative	• 51 unit-based nurses on a critical care unit • 537 patient (pre-intervention), 544 patients (post-intervention)	• Nurses' knowledge significantly improved after education and was retained 4 months after education • QTc interval monitoring protocol improved nurses' ability to identify and monitor patients with increased risk of QTc interval prolongation. Adherence was less than desired.
Tisdale et al., 2020	Current Practice Standards for QTc interval monitoring	Scientific Statement	• Articles from literature search engines: MEDLINE/PubMed, Cochrane Library, Embase, and ClinicalTrials.gov	• Outlines numerous QTi prolonging medications/drugs that can provoke TdP, risk factors, and electrocardiographic and other monitoring strategies

Appendix C

Office of Research Compliance
Human Studies Program

UNIVERSITY of HAWAI'I SYSTEM

August 31, 2022

MEMORANDUM

TO: Rick Ramirez, DNP, APRN-Rx, AG-ACNP-BC, FNP-BC, ENP-C, CEN, CPEN
Doctor of Nursing Practice Program Director and Assistant Professor
AG-PCNP Specialty Coordinator
APRN Clinical Course Series Faculty Coordinator
University of Hawai'i at Mānoa
School of Nursing and Dental Hygiene

FROM: Victoria Rivera
Director, Office of Research Compliance, Human Studies Program
University of Hawaii

SUBJECT: Doctor of Nursing Practice Program

This memorandum intends to clarify the University of Hawaii (UH), Human Studies Program (HSP) position regarding the quality improvement (QI) project required by the UH School of Nursing and Dental Hygiene's Doctor of Nursing (DNP) Program.

Based on our prior discussions, students enrolled in the DNP Program are required to complete a QI project in order to meet the *AACN Essentials of Doctoral Education for Advanced Nursing Practice* for this professional degree. According to the AACN guidelines, since this is a practice doctorate, "requiring a dissertation or other original research is contrary to the intent of the DNP. The DNP primarily involves mastery of an advanced speciality within nursing practice."

Therefore, by definition, the DNP quality improvement project required by the UH School of Nursing is not considered human subjects research as defined under federal regulations at 45 CFR 46. To very briefly summarize, *research* is a systematic investigation designed to contribute to generalizable knowledge, and *human subject* means a living individual about whom an investigator conducting research obtains 1) data through intervention or interaction with the individual or 2) identifiable private information. Quality improvement/program evaluation focuses on making judgements about the program, to improve or futher develop program effectiveness, and inform decisions about future programming. As part of the DNP program, students are familiarized with the difference between conducting a QI project and a research project.

Given the purpose of the DNP quality improvement project, it is the position of the UH Human Studies Program that these projects are considered "NOT human subjects research" (NHSR) and as such, does not require IRB review. To be clear, this is not a determination of "Exempt" status under 46.101, as these are categories of *research* considered to be exempt from IRB review. Please ensure that DNP students understand that the results of these types of QI projects may be presented or published, but must not be labled as human subjects research.

Please feel free to contact our office for any questions.

copy: Allison Tse, SODNH Department Chair and Graduate Chair

2425 Campus Road, Sinclair 10
Honolulu, Hawai'i 96822
Telephone: (808) 956-5007 • Fax: (808) 956-9150

Appendix D

THE QUEEN'S MEDICAL CENTER

RESEARCH & INSTITUTIONAL REVIEW COMMITTEE
1301 Punchbowl Street, University Tower 5th Floor • Honolulu, HI 96813
Ph: 808-691-4512 • Fax: 808-691-7897 • www.queens.org

April 20, 2023

Johanna Au
1161 Wainiha St. #F
Honolulu, HI 98625

RE: Project Title: Improving Nurses' Corrected QT Interval Monitoring On A Telemetry Unit

Dear Ms. Au,

It is understood that you are a QMC employee working on your DNP project.
Based on documents reviewed:

- DNP Project Proposal version received 2-9-2023
- With email clarification received 4-12-2023

as defined under federal regulations 45 CFR 46, this project is determined to be NOT human subjects research and does not required RIRC review. As per the proposal this is a quality improvement project Please note, this is not a determination of "exempt" under CFR46.104.

Should your project change, a re-evaluation will be necessary. Please contact Ms. Ohta at 808-691-4016/rohta@queens.org or Ms. Denise Lin-Deshetler at 808-691-7986/ dlindeshetler@queens.org .

Thank you.

Sincerely.

Danny Takanishi, MD
Interim Chairman, Research and Institutional Review Committee

Cc: file

Appendix E

Aloha everyone,

I am working alongside the QMC electrophysiology (EP) team to implement a quality improvement project about QTc interval monitoring to improve awareness, prevention, and recognition of the early warning signs of possible impending torsades de pointes (TdP) among nurses. To help us determine if this in-service would benefit telemetry nurses, we have chosen P5 nurses to help us. We would like you to participate by completing these pre-post presentation questions and watching a recorded evidence-based QT-educational PPT presentation.

The quality improvement project is divided into three sections:

1) Pre-PPT presentation questions
Google Form Link: https://forms.gle/5KTGWLuzLpuU3Evw6

2) QT educational PPT presentation (~16-min video)
Youtube Link: https://youtu.be/-npi6dQX4Ag

3) Post-PPT presentation questions
Google Form Link: https://forms.gle/vM3uuxX1VcAND2SV8

• It must be completed in this numerical order. Please complete the pre-presentation questions before viewing the recorded PPT presentation and the post-presentation questions after viewing the recorded PPT presentation.

• It should take about 30-40 minutes to complete. It is advised to complete it in one sitting, but if you are unable to, please remember to complete all three sections :)

• Participation is voluntary, but participating may increase your QTc knowledge, so please consider participating!

• All responses will remain anonymous.

• I appreciate your consideration in participating, thank you in advance!

Kind regards,
Johanna Au

Appendix F

6/21/23

QTc Interval Monitoring and Torsades de Pointes

Johanna Au, RN, DNP candidate

Created: May 2023

THE QUEEN'S HEALTH SYSTEMS

1

Objectives

- Describe the clinical relevance of QTc interval prolongation and Torsades de Pointes (TdP)
- Discuss characteristic patterns and ECG signs of TdP
- Identify general TdP risk factors in hospital settings
- List medications that may prolong the QTc interval and/or cause TdP
- Define prolonged QT interval
- Discuss overview of QTc interval monitoring

2

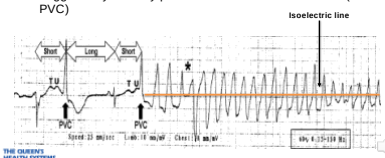
QTc Interval Prolongation and Significance

- Rate corrected QT (QTc) interval prolongation can lead to a ventricular arrhythmia known as *torsades de pointes* (TdP), which can result in sudden cardiac death (SCD)
- Hospitalized patients are thought to have the greatest risk for QTc prolongation and TdP
- The possibility of TdP may be anticipated by the detection of an increasing QTc interval and other premonitory ECG signs
- If these ECG harbingers of TdP are recognized by nurses, it becomes possible to discontinue the offending drug (if any) and manage concomitant conditions (e.g., hypokalemia, bradyarrhythmia) to reduce the occurrence of TdP and SCD, respectively

3

Characteristic Pattern of TdP

- TdP is a *pause-dependent polymorphic ventricular tachycardia* characterized by a pattern of twisting points. It exhibits distinct characteristics on the ECG:
  - Twisting of the QRS complex around the isoelectric baseline
  - Prolonged QT interval
  - Preceded by short-long-short sequence of R-R intervals
  - Triggered by an early premature ventricular contraction (R-on-T PVC)



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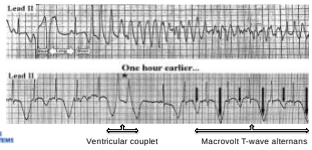
Premonitory ECG Signs of TdP

- Marked QTc prolongation
  - QTc > 500 ms is associated with 2-3-fold higher risk for TdP
  - Increase in QTc from predrug baseline of 60ms
- Bradycardia or long pauses (e.g., compensatory pauses after ventricular ectopy)
- T wave alternans (every other T wave is taller)
- New-onset ventricular ectopy, couplets, and nonsustained polymorphic ventricular tachycardia



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General TdP Risk Factors in Hospital Settings

- TdP can be caused by either congenital long QT-syndrome or acquired long QT-syndrome (e.g., electrolyte abnormalities and/or medications)
- In hospitalized patients, TdP commonly associated with acquired QTc prolongation, with or without genetic predisposition, often in the presence of a QT-prolonging drug

	Examples
General risk factors	
Older age	
Female sex	
Heart disease	Left ventricular hypertrophy Low left ventricular ejection fraction Myocardial ischemia
Bradyarrhythmia	Pause after conversion from AF or flutter to sinus rhythm Compensatory pauses after PVCs Sinus pauses Mobitz II or complete heart block with ventricular rate <40 bpm
Electrolyte abnormalities	Hypokalemia (moderate to severe) Hypomagnesemia (moderate to severe) Malnutrition electrolyte disorders
Metabolic impairment (acquired or genetic)	Renal failure Hepatic failure
Genetic predisposition to QT prolongation	Unexplained QT prolongation in patient or family member Family history of syncope, sudden death, LQTS
Concomitant use of drugs that prolong QT or impair their metabolism	

6

6/21/23

Medications

- Weigh risk vs. benefits of therapy
  - Is there any alternative medication with similar benefit?
  - Assess risk for QT prolongation
    - Patient risk factors
    - Concurrent medications
    - Drug properties (e.g., renally excreted, CYP450 interactions

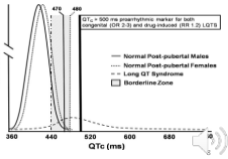
Drug Class	Examples
Antiarrhythmic	Amiodarone, disopyramide, dofetilide, ibutolide, sotalol
Antibiotic	Azithromycin, ciprofloxacin, erythromycin, levofloxacin, moxifloxacin
Antidepressant	Citalopram, escitalopram
Antiemetic	Droperidol, ondansetron, promethazine
Antifungal	Fluconazole
Antipsychotic	Haloperidol, chlorpromazine
Opiate	Methadone

- Drugs that may provoke TdP are cataloged in the regularly updated QT drugs list that is maintained by the Arizona Center for Education & Research on Therapeutics (AZCERT). For a more extensive list: http://www.crediblemeds.org

7

Definition of Prolonged QTc Interval

- Normal QTc is <450 ms in male adults and <460 ms in female adults
- QTc interval over the 99th percentile should be considered abnormally prolonged
- Varies among men and women
  - Approximate 99th percentile QTc values are 470 ms for males and 480 ms for females
  - QTc > 500ms is considered highly abnormal for both males and females and associated with higher risk for TdP
- Note: Some standard 12-lead ECG algorithms label a QT_c > 440 ms as borderline QT prolongation, even though this value is exceeded by approximately 10% to 20% of the population



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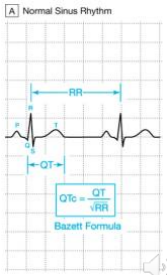
Methods to Monitor QT/QTc in Hospital Settings

- Manual measurement
- Electronic Calipers (*currently used by QMC nurses)
- Fully Automated QT/QTc Monitoring
  - Often unreliable and may under/overestimate QT
- No research studies to indicate the best method for monitoring QT/QTc intervals in hospital settings. The key is using a single consistent method. This includes:
  - Measurement equipment
  - Lead-selection criteria (e.g., the lead that has a visible T wave with a clear-cut ending)
  - Use of a consistent lead in the same patient over time
  - Method to identify QRS onset and T-wave offset
  - QT correction formula
  - Frequency of measurement
  - Documentation procedure

9

Measuring QTc Interval

- QT interval varies based on the patient's heart rate
  - Slow heart rate = QT interval lengthens
  - Fast heart rate = QT interval shortens
- Various formulas for adjusting QT for heart rate
  - When otherwise not stated, QTc generally refers to the Bazett correction



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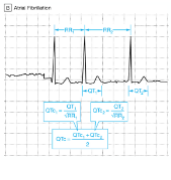
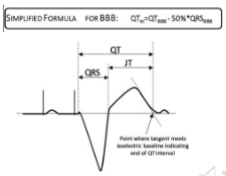
Confounders of Accurate QT Interval Measurement

- Atrial fibrillation
- Bundle Branch block
  - An increase of the QT interval due to a new conduction block should not be considered indicative of acquired long QT syndrome





11

Recommended QTc Monitoring for Hospitalized Adult Patients by Population

Class I – QTc monitoring is recommended

- Initiation of an antiarrhythmic drug known to cause TdP with or without risk factors
- Initiation of a nonantiarrhythmic drug known to cause TdP with history of prolonged QTc or with general risk factors

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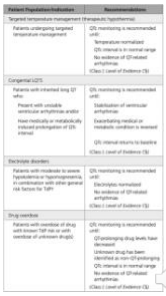
Recommended QTc Monitoring for Hospitalized Adult Patients by Population Cont.

Class I – QTc monitoring is recommended

- Undergoing targeted temperature management
- Inherited long QT with unstable ventricular arrhythmias and/or have medically or metabolically induced QTc interval prolongation
- Moderate to severe hypokalemia or hypomagnesemia
- Overdose of drugs with known TdP risk or unknown drug(s)
- New onset bradyarrhythmias



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Recommended QTc Monitoring for Hospitalized Adult Patients by Population Cont.

Class II – QTc monitoring may be reasonable

- Initiation of an antiarrhythmic drug with possible risk for TdP with or without risk factors
- Initiation of a nonantiarrhythmic drug with possible risk for TdP with history of prolonged QTc or with general risk factors
- Acute neurological events with baseline QTc prolongation

Patient Population/Indication	Recommendations
Drug initiation*	
Patients with or without risk factors for TdP† who are started on antiarrhythmic drugs with possible risk for TdP Medications include amiodarone, dronedarone, flecainide	QTc monitoring may be reasonable (Class IIb; Level of Evidence C‖)
Patients with history of prolonged QTc or with general risk factors for TdP† who are started on nonantiarrhythmic drugs with risk for TdP Drugs with possible or conditional risk	QTc monitoring is reasonable (Class IIa; Level of Evidence C‖)

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Recommended QTc Monitoring for Hospitalized Adult Patients by Population Cont.

Class III – QTc monitoring is not recommended

- Healthy patients administered nonantiarrhythmic drugs that pose known or possible risk for TdP
- Acute neurological events with no baseline QTc prolongation

Patient Population/Indication	Recommendations
Drug initiation*	
Patients without history of prolonged QTc or without general risk factors for TdP† who are started on nonantiarrhythmic drugs with risk for TdP	QTc monitoring is not recommended
Drugs with known risk	*Class III: No Benefit; Level of Evidence C*
Drugs with possible or conditional risk	*Class III: No Benefit; Level of Evidence C*
Acute neurological event	
Patients with acute neurological events and no baseline QTc prolongation	QTc monitoring is not recommended (*Class III: No Benefit; Level of Evidence C*)

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General Principals for QTc Monitoring

- For patients with Class I indication for QT monitoring, document the QTc, including rhythm strip, in patient's medical record at baseline and then at least every 8-12 hours
- If QTc prolongation occurs during administration of drug, more frequent measurement may be needed
- Document QTc before and after increases in dose of QT-prolonging drug
- In patients who develop QTc > 500 ms or an increase of > 60ms, discontinue causative drug and continue QTc monitoring until drug washes out and QTc is documented to be decreasing
- Decision to hold drug will vary on the basis (e.g., may not need to hold amiodarone); consult an expert on whether is continue drug when QT prolongation is observed

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References

Al-Khatib, S. M., LaPointe, N. M. A., Kramer, J. M., & Califf, R. M. (2003). What clinicians should know about the QT interval. *Jama*, *289*(16), 2120-2127.

Bogossian, H., Linz, D., Heijman, J., Bimpong-Buta, N. Y., Bandorski, D., Frommeyer, G., ... & Ciljns, H. J. (2020). QTc evaluation in patients with bundle branch block. *IJC Heart & Vasculature*, *30*, 100636

Drew, B. J., Califf, R. M., Funk, M., Kaufman, E. S., Krucoff, M. W., Laks, M. M., ... & Van Hare, G. F. (2004). Practice standards for electrocardiographic monitoring in hospital settings: An american heart association scientific statement from the councils on cardiovascular nursing, clinical cardiology, and cardiovascular disease in the young: Endorsed by the international society of computerized electrocardiology and the american association of critical-care nurses. *Circulation*, *110*(17), 2721-2746. doi.org/10.1161/01.CIR.0000145144.56673.59

Drew, B. J., Ackerman, M. J., Funk, M., Gibler, W. B., Kligfield, P., Menon, V., ... & Zareba, W. (2010). Prevention of torsade de pointes in hospital settings: A scientific statement from the american heart association and the american college of cardiology foundation. *Journal of the American College of Cardiology*, *55*(9), 934-947. doi.org/10.1016/j.jacc.2010.01.001

Sandau, K. E., Funk, M., Auerbach, A., Barsness, G. W., Blum, K., Cvach, M., ... & Wang, P. J. (2017). Update to practice standards for electrocardiographic monitoring in hospital settings: A scientific statement from the american heart association. *Circulation*, *136*(19), e273-e344. doi.org/10.1161/CIR.0000000000000527

Schurr, J. W., Grewal, P. K., Fan, R., & Rashba, E. (2022). QT interval measurement in ventricular pacing: Implications for assessment of drug effects and pro-arrhythmia risk. *Journal of Electrocardiology*, *70*, 13-18

Tisdale, J. E., Chung, M. K., Campbell, K. B., Hammadah, M., Joglar, J. A., Leclerc, J., ... & American Heart Association Clinical Pharmacology Committee of the Council on Clinical Cardiology and Council on Cardiovascular and Stroke Nursing. (2020). Drug-induced arrhythmias: A scientific statement from the american heart association. *Circulation*, *142*(15), e214-e233. doi.org/ 10.1161/CIR.0000000000000905

QT-interval measuring, manual. (2018). In Lippincott procedures. Retrieved from http://procedures.lww.com

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Mahalo!

18

Appendix G

QT Knowledge Test

Please answer the following questions:

1)

An ECG is done on a 45-year-old woman who presents with cyclical emesis, palpitations, and near syncope. What diagnosis can you make from this ECG? (Choose one)

a. Supraventricular tachycardia
b. Premature ventricular contractions (PVCs)
c. Monomorphic ventricular tachycardia
d. Torsades de pointes

2) A lengthened QT interval will place the patient at risk for which arrhythmia? (Choose one)

a. Atrial flutter
b. Torsades de pointes
c. Wolff-Parkinson-White syndrome
d. Ventricular fibrillation
e. Junctional tachycardia

3) What condition can result in a prolonged QT interval? (Choose one)

a. Congenital long QT syndrome
b. Hypokalemia
c. Hypomagnesemia
d. Bradycardia
e. All of the above

4) According to the American Heart Association guidelines, how often should the QT interval be documented in a patient receiving cardiac monitoring? (Choose one)

a. When QT-related arrhythmias occur
b. Only with ST elevation
c. When hypokalemia occurs
d. Minimum once per shift, more if QT interval is increasing

5) Corrected QT intervals show what the interval would be if the heart rate were: (Choose one)

a. 80 beats per minute
b. 75 beats per minute
c. 100 beats per minute
d. 60 beats per minute

6) Which patient would be a **"top priority"** for QT-interval monitoring? (Choose one)

a. 50-year-old man with hypertension
b. 25-year-old woman with a known methadone overdose
c. Elderly woman with shortness of breath
d. 75-year-old man after cardiac surgery

7) A patient on a telemetry monitor unit develops an increase in QTc interval from 0.44 seconds to 0.52 seconds. The change in QTc interval may not be abnormal if which of the following conditions has developed? (Choose one)

a. Patient has renal insufficiency
b. Patient has left bundle-branch block
c. Patient has no history of congenital long QT syndrome
d. Patient has normal electrolyte levels

8) You administer ibutilide (Corvert) intravenously in a patient who comes to the emergency department with new-onset atrial fibrillation. If this drug causes torsades de pointes, when is it most likely to happen? (Choose one)

a. 4-6 hours after administration
b. 6-24 hours after drug administered
c. When the patient converts to sinus rhythm (typically within 30 minutes of drug administration)
d. Can occur anytime during the 72 hours following drug administration

9) The most common cause of torsades de pointes is acquired prolongation of the QT interval due to medication(s). All of the following are QT interval-prolonging drugs known to cause torsades de pointes, **except** which one? (Choose one)

a. Ciprofloxacin
b. Ondansetron
c. Promethazine
d. Pantoprazole

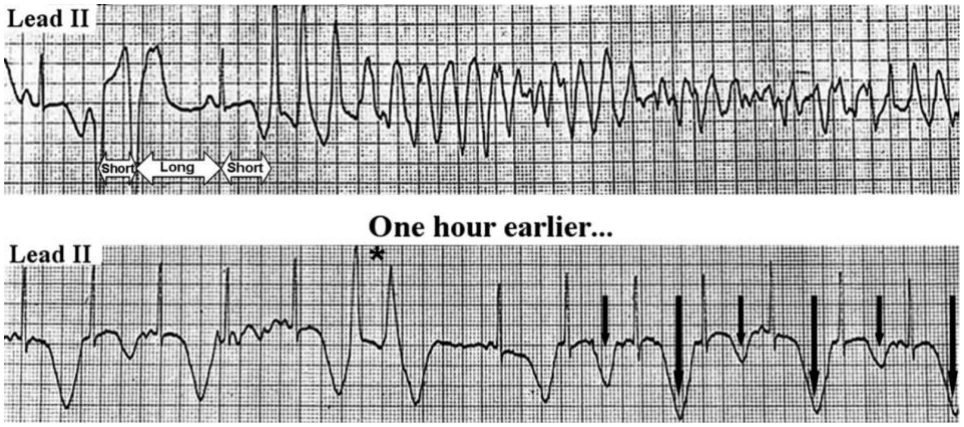
10) The prolongation of the QT interval to longer than what value (ms) during drug therapy should prompt a critical re-evaluation of that therapy and consideration of therapeutic alternatives? (Choose one)

a. 460 ms
b. 480 ms
c. 500 ms
d. 560 ms

11) All of the following are characteristic ECG signs of torsades de pointes, **except** which one? (Choose one)

a. Preceded by a sequence of short-long-short R-R intervals
b. Twist of the QRS complexes around the isoelectric line
c. A short PR interval and a delta wave
d. Triggered by an early R-on-T PVC

12)



The top rhythm strip shows torsades de pointes in an 83-year-old female hospitalized for pneumonia. She was started on intravenous erythromycin several hours before cardiac arrest. The bottom rhythm strip shows the ECG done 1 hour before the onset of torsades de pointes. All of the following are ECG signs of impending torsades de pointes, **except** which one? (Choose one)

a. Nonsustained monomorphic ventricular tachycardia (unifocal)
b. QTc interval > 0.50 seconds
c. T wave alternans
d. New-onset polymorphic ventricular ectopy and couplets

Appendix H

QT Self-efficacy Questionnaire:

(Point: 1 = Not at all confident, 2 = Somewhat confident, 3=Moderately confident, 4=Very confident, 5= Completely confident)

Please answer the following questions:

1) How confident are you in identifying patients who require QTc interval monitoring?
   a. Not at all confident
   b. Somewhat confident
   c. Moderately confident
   d. Very confident
   e. Completely confident

2) How confident are you in accurately performing QTc interval monitoring?
   a. Not at all confident
   b. Somewhat confident
   c. Moderately confident
   d. Very confident
   e. Completely confident

3) How confident are you in notifying MD of prolonged QTc intervals?
   a. Not at all confident
   b. Somewhat confident
   c. Moderately confident
   d. Very confident
   e. Completely confident

4) How confident are you in recognizing the risk factors for torsades de pointes?
   a. Not at all confident
   b. Somewhat confident
   c. Moderately confident
   d. Very confident
   e. Completely confident

5) How confident are you in recognizing the early ECG warning signs of torsades de pointes?
   a. Not at all confident
   b. Somewhat confident
   c. Moderately confident
   d. Very confident
   e. Completely confident

6) How confident are you in recognizing torsades de pointes on a telemetry monitor?
   a. Not at all confident
   b. Somewhat confident
   c. Moderately confident
   d. Very confident
   e. Completely confident