Original Article

Exploring electrocardiographic alterations and the prolongation of QT interval in patients with diabetes mellitus

Tushar Arya[1], Rajendra Kumar[2], Tarique Aziz[3], Md Shadab Alam[4], Anit Kujur[5]

[1]Department of Physiology, Medinirai Medical College, Palamu, Jharkhand, India, [2]Department of Physiology, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India, [3]Department of Biochemistry, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India, [4]Department of Pharmacology and Therapeutics, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India, [5]Department of Community Medicine, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India

Abstract

Background: Diabetes mellitus (DM) affects a substantial proportion of the world's population and is associated with an increased risk of sudden cardiac death (SCD) due to cardiac arrhythmias, specifically prolonged QT intervals. This study investigates the correlation between glycemic control and cardiac health in 77 diabetic patients. **Methods:** Patients with both type 1 and type 2 DM aged 14 to 82 years were included. Various clinical and metabolic parameters were evaluated, including glycated hemoglobin (HbA1C). QT intervals were measured using electrocardiograms (ECGs), and patients were categorized based on their QTc intervals. SPSS was used for statistical analysis, including one-way ANOVA tests. **Results:** The study revealed diverse age and gender representation among diabetic patients. Most patients had type 2 diabetes (87%) with varying illness durations. Patients ranged in age from 14 to 82 years, with a mean of 48.14 16.58 years. The gender distribution was even (49% male and 51% female). Most participants had diabetes for less than five years (57%) and varied treatment histories (71% managed with oral hypoglycemic agents, 17% with insulin, and 12% with a combination). The ECG revealed ST-T alterations (4%) as well as sinus tachycardia (13%) and left ventricular hypertrophy (19%). **Conclusion**: This study sheds light on the intricate relationship between diabetes, glycemic control, and cardiac health. QTc interval variations were observed even though the clinical and metabolic profiles of the patients varied. The influence of glycemic control on QT intervals and cardiovascular outcomes in diabetic patients requires additional study.

Keywords: Diabetes mellitus, electrocardiogram, glycemic control, one-way ANOVA, QT interval, sudden cardiac death

Introduction

Diabetes mellitus (DM) significantly impacts approximately 9% of the global adult population, comprising both type 1, or insulin-dependent diabetes mellitus (IDDM), and type 2, or noninsulin-dependent diabetes mellitus (NIDDM).[1] DM's prevalence is on a sharp rise, with projections indicating that over 552 million individuals will be affected by 2030, and India currently hosts 72 million cases, earning the title of the "diabetic capital of the world."[1] Type 1 diabetes results from near-total insulin deficiency, while type 2 diabetes represents a heterogeneous group characterized by varying insulin resistance, impaired insulin secretion, and increased glucose production.

Individuals with DM face a heightened 2- to 10-fold risk of sudden cardiac death (SCD),[2] mainly due to fatal cardiac

Address for correspondence: Dr. Anit Kujur, Department of Community Medicine, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India.
E-mail: kujuranit@yahoo.com

Received: 04-05-2024 **Revised:** 25-05-2024
Accepted: 15-06-2024 **Published:** 18-11-2024

Access this article online

Quick Response Code:

Website: http://journals.lww.com/JFMPC

DOI: 10.4103/jfmpc.jfmpc_747_24

How to cite this article: Arya T, Kumar R, Aziz T, Alam MS, Kujur A. Exploring electrocardiographic alterations and the prolongation of QT interval in patients with diabetes mellitus. J Family Med Prim Care 2024;13:5033-9.

arrhythmias. Prolonged QT intervals serve as a quantifiable risk measure, yet clinician awareness of this risk remains limited. Even after adjusting for conventional cardiovascular risk factors,[3] excess cardiovascular risk persists in diabetic patients, possibly stemming from mechanisms like ventricular instability, indicated by QT abnormalities.

Notably, the prevalence of prolonged QTc intervals is elevated in both type 1 and type 2 DM,[4] particularly in older patients with higher blood pressure (BP),[5] leading to increased cardiovascular complications. Surprisingly, even recently diagnosed diabetic patients exhibit prolonged QTc intervals without apparent cardiac complications,[6] emphasizing the complexity of this issue.

While the exact reasons behind QT abnormalities in diabetes remain unclear,[7] some studies suggest a link between uncontrolled hyperglycemia, QT prolongation, and increased cardiovascular mortality.[7] Exploring the influence of hyperglycemia on QT abnormalities is vital, as it may induce ventricular instability through factors like increased sympathetic activity and altered cytosolic calcium content in myocytes.[8] Insulin's role in stimulating sympathetic activity and the impaired parasympathetic cardiac control seen in diabetes add to this complexity.[9]

Currently, no studies have assessed the impact of controlling hyperglycemia on QTc and QT prolongation in diabetic patients.[10] Thus, it is essential to determine whether aggressive hyperglycemia control can mitigate QT abnormalities and improve cardiac outcomes without affecting QT intervals independently. It will be helpful for family physicians in identifying diabetic patients at high risk for adverse cardiovascular outcomes through increased QT intervals is an intriguing possibility, allowing for targeted investigations such as treadmill tests, echocardiograms, and angiography.

The present study aims to explore the intricate connection between diabetes and QT abnormalities in relation to cardiovascular risk. We aimed to determine the prevalence of QTc prolongation in individuals with DM and assess the occurrence of QTc shortening in the same population along with the relationship between the duration of diabetes and QTc intervals. Lastly, we endeavor to establish a correlation between QTc intervals and glycated hemoglobin (HbA1C) levels in DM patients.

Materials and Methods

Ethical approval and study setting

The study was carried out at the Rajendra Institute of Medical Sciences (RIMS) in Ranchi, Jharkhand, within the premises of a teaching hospital. Ethical approval for this study was obtained from the Institutional Ethics Committee at RIMS, Ranchi, Jharkhand, under Memo No. 268IEC, RIMS, Dt. 13.06.2021. The study strictly followed the ethical guidelines to ensure accuracy and reliability. Participants were provided with comprehensive information about the study's objectives and procedures. Their participation was entirely voluntary, and informed consent was obtained to ensure their complete understanding and willingness to participate.

Patient selection

A total of 77 patients diagnosed with DM, who were admitted between July 2021 and September 2022, were randomly selected for this study. These patients covered diverse age groups and had varying durations of illness. Both male and female patients meeting the inclusion criteria willingly provided written consent and assent.

Inclusion criteria

Patients eligible for inclusion encompassed those with diagnosed cases of DM, including both type I and type II, as per the American Diabetes Association (ADA) criteria. These criteria involved glycosylated hemoglobin (HbA1C) levels > 6.5%, fasting blood glucose levels > 126 mg/dl (7.0 mmol/L), post-prandial glucose levels > 200 mg/dl (11.1 mmol/L), or random blood glucose levels > 200 mg/dl (11.1 mmol/L). Patients of both genders above 14 years of age who were on insulin, oral hypoglycemic agents, or a combination of both were included in the study.

Exclusion criteria

Exclusion criteria comprised patients with known cardiovascular diseases, chronic complications of DM, chronic diseases such as chronic kidney disease, chronic obstructive pulmonary disease, and thyroid disorders. Patients exhibiting electrolyte disturbances like hypocalcemia or hypokalemia were excluded. Additionally, patients on drugs known to induce QT prolongation (e.g., digitalis, quinidine, procainamide, and tricyclic-antidepressants), individuals with hereditary long QT intervals, and those with conditions shortening the QTc interval were excluded from the study.

Sample size calculation

The sample size was determined using a formula for sample size calculation. A 95% confidence interval was used, with a prevalence of DM in Jharkhand estimated at 5.3% based on the 2011 ICMR-INDIAB study. This calculation resulted in a required sample size of 77.

Medical history and clinical examination

Detailed records of the duration of DM were meticulously documented during the initial phase. Clinical examinations were performed to assess the presence of diabetic cases. Furthermore, a battery of tests was administered to establish the diagnosis of DM.

Blood sugar assessment

Random blood sugar levels were determined using venous blood samples analyzed through the glucose hexokinase assay method. The estimation of HbA1C levels was conducted using the HPLC-high-performance liquid chromatography technique.

Electrocardiographic study

An electrocardiographic (ECG) study was conducted employing the BPL CARDIART 6208 model machine. The ECG assessed various parameters including heart rate, rhythm, ST-T changes, PR interval, QRS duration, QT interval, and QTc interval. The latter was calculated using Bazzet's formula with the assistance of an online calculator.[11]

Glucose assessment method

Random glucose levels were determined from venous blood samples employing the glucose hexokinase assay. The assay utilized the hexokinase method to measure glucose levels, which is based on the conversion of NADH from NAD at 340 nm. The increase in optical density (O.D.) was measured at fixed intervals, and the plasma glucose levels were calculated using the formula delta O.D./min (test)/delta O.D./min (std.) × 100.

HbA1C assessment method

The estimation of HbA1C levels was conducted through the HPLC-high-performance liquid chromatography method using a Biorad-10 machine. The diagnosis of DM relied on HbA1C levels exceeding 6.5% as per the ADA criteria.

QT interval measurement

The QT interval was measured from the commencement of the QRS complex to the end of the T wave at the intersection with the isoelectric line. The QTc (QT corrected for the length of the previous cycle) was calculated using Bazett's formula: QTc = QT $\sqrt{}$ RR. A QTc measurement exceeding 440 msec was considered abnormally prolonged, while a measurement below 350 msec indicated shortening. The normal range for QTc, measured in milliseconds, fell between 350 and 440 msec.

Statistical analysis

Using SPSS, the statistical analysis of the study's data was conducted after its collection. To evaluate the correlation between the study parameters, *F*-values and *P* values were computed using one-way ANOVA tests.

Results

The present study investigated the potential relationship between QTc prolongation and glycemic control in a cohort of 77 diabetic patients. These patients encompassed a wide range of ages and varied durations of diabetes. The patient's average age was 48.14 ± 16.58 years, with the youngest being 14 and the oldest 82 [Table 1]. In terms of the distribution of our diabetic patient cohort by gender, we observed a balanced representation, and out of the total 77 cases, 38 patients (49%) were male, while 39 patients (51%) were female. Our study encompassed two main types of DM, and most cases fell under type 2 diabetes (67 patients; 87%) while the remaining 10 patients (13%) had type 1 diabetes, out of the total 77 cases [Table 1]. The study found that patients under 30 years old constituted 10 cases (13%), those aged 31 to 40 accounted for 6 cases (8%), and the most substantial group was in the 41 to 50 age bracket with 24 cases (31%). Patients aged 51 to 60 comprised 16 cases (21%), while those aged 61 to 70 constituted 15 cases (19%) and additionally, 6 patients (8%) were over the age of 70 [Table 1].

Table 1: A comprehensive summary and diabetes profile of the study population in the present study

Characteristics	Value
DM cases (no.)	77
Age (years)	
Mean±SD	48.14±16.58
Range	14–82
Patients (no./%)	
Male	38 (49)
Female	39 (51)
Type of DM (no./%)	
Type 1	10 (13)
Type 2	67 (87)
Age distribution of DM (years/no./%)	
<30	10 (13)
31–40	6 (8)
41–50	24 (31)
51–60	16 (21)
61–70	15 (19)
>70	6 (8)
Duration of DM (years/no./%)	
≤5	44 (57)
6–10	18 (23)
11–15	8 (11)
16–20	5 (6)
>21	2 (3)
Treatment history (no./%)	
OHA	55 (71)
Insulin	13 (17)
OHA and insulin	9 (12)
ECG abnormalities	
ST-T changes	3 (4)
Sinus tachycardia	10 (13)
LVH	15 (19)

They investigated different durations of DM within the patient cohort, revealing a distribution among groups. The largest group, constituting 44 patients (57%), had a diabetes duration of 5 years or less, while the next group, comprising 18 patients (23%), had a duration of 6 to 10 years. Eight patients (11%) had diabetes for 11 to 15 years and five patients (6%) for 16 to 20 years. Lastly, two patients (3%) had been living with diabetes for more than 21 years [Table 1]. In our study, we observed various treatment histories for DM within the patient cohort, with 55 individuals (71%) managed with OHA, 13 patients (17%) receiving insulin treatment, and a smaller group of nine patients (12%) requiring both OHA and insulin therapy [Table 1]. In our study of 77 individuals with DM, we identified distinct

ECG findings. ST-T changes were observed in 3 cases (4%), while sinus tachycardia was noted in 10 cases (13%) and left ventricular hypertrophy (LVH) was present in 15 cases (19%) [Table 1].

The study found that the average BMI was 23.50 ± 4.97, ranging from 11.70 to 38.20. The duration of diabetes in years had a mean of 6.42 ± 3.54, with a range of 0.08 to 24 years [Table 2]. The average pulse rate among the patients was 84.29 ± 12.13 beats per min, with a range of 60 to 110. Systolic BP had a mean of 127.80 ± 13.27 mm Hg, with values ranging from 100 to 158. Diastolic BP had a mean of 75.74 ± 8.96 mm Hg, with readings ranging from 54 to 90 [Table 2]. The mean random blood sugar level in mg/dl was 292.04 ± 76.63, with values spanning from 200 to 529. The average HbA1C level was 8.70 ± 1.66%, with a range of 6.6 to 14.2. The mean PR interval was 149.00 ± 20.05 msec, with readings ranging from 104 to 189. The average QT interval was 357.70 ± 28.07 msec, with values ranging from 300 to 421. For the QTc interval, the mean was 421.40 ± 27.42 in msec, with readings spanning from 346 to 489 [Table 2].

The QTc interval, a critical parameter in our study, exhibited a range of values among the diabetic patients [Table 2]. We categorized the patients into three groups based on their QTc intervals: a small subset, consisting of 3 patients (4%), had low QTc intervals measuring below 350 msec; a larger proportion of 53 patients (69%) fell within the normal range, displaying QTc intervals ranging from 350 to 440 msec; however, 21 patients (27%) exhibited high QTc intervals exceeding 440 msec [Table 2].

Examining the random blood sugar levels of our diabetic patients, we observed a spectrum of values within different ranges. A significant portion, comprising 31% (24 cases) of the total cases, had random blood sugar levels falling between 200 and 250 mg/dl, while another substantial group, consisting of 39% (30 cases) of the cases, had random blood sugar levels ranging from 251 to 300 mg/dl [Table 3]. Smaller subsets of patients exhibited blood sugar levels in higher ranges, with 6% (5 cases) of the cases having levels between 301 and 350 mg/dl, 14% (11 cases) between 351 and 400 mg/dl, and 10% (7 cases) with levels exceeding 401 mg/dl [Table 3].

In the current study, the largest portion of patients, accounting for 56% (43 cases) of the total cases, had HbA1C levels ranging from 6.5% to 8.5%, while 29% (22 cases) of the cases exhibited HbA1C levels between 8.6% and 10.5% [Table 3]. Smaller groups of patients had HbA1C levels in higher ranges, with 11% (9 cases) between 10.6% and 12.5%, and 4% (3 cases) of cases exceeding 12.5% [Table 3].

The present study investigated the potential link between diabetes duration and the QTc interval in a group of diabetic patients. The results showed that patients with a diabetes duration of ≤5 years (44 individuals) had a mean QTc interval of 415.4 ± 18.4 msec, while those in the 6 to 10 years category (18 patients) exhibited a mean QTc interval of 416.7 ± 34.9 msec [Table 4]. Patients with a diabetes duration of 11 to 15 years (8 individuals) displayed a mean QTc interval of 440.6 ± 29.6 msec, and in the 16 to 20 years category (5 patients), the mean QTc interval was 455.2 ± 8.8 msec [Table 4]. Finally,

Table 2: Distribution of corrected QT (QTc) intervals and various clinical variables among the patients with diabetes mellitus

Variables	Mean±SD	Min-Max
BMI (kg/m^2)	23.50±4.97	11.70–38.20
Duration of diabetes (years)	6.42±3.54	0.08–24
Pulse rate (per min)	84.29±12.13	60–110
Systolic BP (mm Hg)	127.80±13.27	100–158
Diastolic BP (mm Hg)	75.74±8.96	54–90
Random blood sugar (mg/dl)	292.04±76.63	200–529
HbA_1C (%)	8.70±1.66	6.6–14.2
PR interval (msec)	149.00±20.05	104–189
QT interval (msec)	357.70±28.07	300–421
QTc interval (msec)	421.40±27.42	346–489
QTc interval	**Range (msec)**	**DM cases (no./%)**
Low	<350	3 (4)
Normal	350–440	53 (69)
High	>440	21 (27)

Table 3: Random blood sugar level and HbA1C level distribution in DM cases

	DM cases (no./%)
Random blood sugar level (mg/dl)	
200–250	24 (31)
251–300	30 (39)
301–350	5 (6)
351–400	11 (14)
>401	7 (10)
HbA1C level (%)	
6.5–8.5	43 (56)
8.6–10.5	2 (29)
10.6–12.5	9 (11)
>12.5	3 (4)

Table 4: Association between duration diabetes and glycosylated hemoglobin (HbA1C) with QTc interval in diabetic patients

	Patients (*n*)	QTc interval (msec) (mean±SD)	One-way ANOVA test	
			F	*P*
Duration of diabetes (years)				
≤5	44	415.4±18.4	1.417	0.0001
6–10	18	416.7±34.9		
11–15	8	440.6±29.6		
16–20	5	455.2±8.8		
>21	2	443.1±60.8		
HbA1C level (%)				
6.5–8.5	43	411.7±24.4	1.289	0.0001
8.6–10.5	2	430.8±25.1		
10.6–12.5	9	437.1±31.2		
>12.5	3	445.3±24.5		

patients living with diabetes for more than 21 years (2 individuals) showed a mean QTc interval of 443.1 ± 60.8 msec. A one-way ANOVA test revealed a significant association between diabetes duration and QTc interval ($F = 1.417$, $P = 0.0001$) [Table 4].

In the diabetic patient cohort, HbA1C levels ranged from 6.5 to 8.5% for 43 individuals, with a mean QTc interval of 411.7 ± 24.4 msec [Table 4]. Patients with HbA1C levels in the 8.6 to 10.5% range (22 patients) had a mean QTc interval of 430.8 ± 25.1 msec, while those with HbA1C levels between 10.6 and 12.5% (9 individuals) showed a mean QTc interval of 437.1 ± 31.2 msec [Table 4]. Patients with HbA1C levels exceeding 12.5% (3 patients) had a mean QTc interval of 445.3 ± 24.5 msec. A one-way ANOVA test resulted in an F value of 1.289 and a P value of 0.0001, indicating a statistically significant association between HbA1C levels and the QTc interval in the studied diabetic patient population [Table 4].

Discussion

Diabetes affects the cardiovascular and autonomic nervous systems, resulting in QTc interval prolongation, a risk factor for SCD. As cardiovascular disease is the leading cause of death in people with diabetes, additional biomarkers are required. Glycemic variability and prolonged hyperglycemia are associated with increased mortality and complications. Electrocardiography can detect early pathological cardiac changes, including prolonged QT intervals, which increase the risk of arrhythmia and SCD.

The complex relationship between glycemic control and cardiac health in 77 diverse diabetics is examined in this study. The findings are significant and relevant to diabetes management. Participants ranged in age from 14 to 82, which is notable. This complicated age distribution shows that diabetes affects all ages. Rosenbauer *et al.*[12] stressed the need to treat diabetes holistically throughout life, which supports this diversity. Planning for an almost identical gender distribution (49% male, 51% female) [Table 1] is crucial for our study. Numerous studies have shown gender differences in diabetes outcomes, according to Gisinger *et al.*[13] By maintaining a balanced representation, we reduce gender-based bias in our findings, improving their reliability and robustness. Most of our participants (87%), had type 2 diabetes, while 13% had type 1. This distribution closely matches diabetes-type prevalence in real life. This alignment boosts our findings' external validity, making them applicable to a larger and more diverse diabetic population. Similar to Gisinger *et al.*,[13] type-specific interventions are important in research.

The age distribution of our diabetic patients has provided intriguing insights into the relationship between age and QTc prolongation in diabetes. A large proportion of our patients are between 41 and 50, suggesting a link between QTc prolongation and 40s age. The high proportion of patients over 70 in our cohort is equally important as this thought-provoking observation. This demographic diversity raises intriguing questions about how aging affects diabetic QTc intervals. It suggests that age may affect QTc intervals beyond middle age, and understanding these age-related dynamics is crucial for patient management. Our findings also suggest that age-related factors that prolong QTc in diabetes need further study. This includes assessing lifestyle factors and comorbidities that may affect diabetics' cardiac health with age. Our cohort has a diverse diabetes duration pattern, requiring attention. A large percentage of patients had a 5-year lifespan or less, suggesting early QTc prolongation in diabetes. This is consistent with Banerjee *et al.*,[14] who found that complications can arise shortly after diagnosis, with a mean diabetes duration of 4.5 years. Conversely, some patients had diabetes for over 21 years. Long-term diabetes monitoring is important because it may pose cardiac health and QTc interval challenges.

In-depth treatment histories show the complexity of diabetes management. OHA, a standard type 2 diabetes treatment, was used for most patients. A significant number needed insulin, and a smaller subset needed both OHA and insulin. Diabetes management is complex, as shown by this treatment variety. Sinus tachycardia, prolonged QTc, QT dispersion, HRV changes, ST-T changes, and LVH can appear early in diabetes progression, according to Stern and Sclarowsky.[15] Our research also found ECG abnormalities in diabetics, supporting these findings.

Our patients had an average BMI of 23.50 ± 4.97, which was healthy [Table 2]. Even though BMI is a good indicator of health, the relationship between BMI and QTc prolongation is crucial.[16] Understanding how BMI affects QTc intervals in diabetics may shed light on the complex relationship between weight management and cardiac health in this population. Additionally, our patient population has diabetes durations from 0.08 to 24 years, which must be noted. Due to its wide range of effects on cardiovascular complications, diabetes duration deserves attention. These complications are more likely with longer-term diabetes.[16] The average pulse rate among our patients was 84.29 beats per minute, with SBP at 127.80 mm Hg and DBP at 75.74. These vital parameters help assess cardiac health and may reveal QTc interval variations.

Rodriguez *et al.*[17] found that systolic BP above 115 mm Hg increases heart disease risk. However, it is unclear if keeping SBP below 120 mm Hg in adults with hypertension (HTN) reduces heart failure, stroke, and myocardial infarction. These findings emphasize the importance of SBP monitoring in cardiac health assessment. Our study also examined random blood glucose levels, which averaged 292.04 mg/dl, and HbA1C, which was 8.70%. These values reveal our patient cohort's glycemic control. Poor blood sugar management is known to cause diabetes complications.[17] Thus, understanding the relationships between these glycemic markers and QTc intervals is crucial to understanding diabetes-related cardiac complications. We found a variety of QTc values in diabetics. A small subset (4%) had low QTc intervals, 69% were within the normal range (350–440 msec), and 27% were high. This stratification suggests

widespread QTc interval variability in diabetics, emphasizing the need for individualized clinical assessment and treatment.

Our study of diabetic patients' random blood sugar levels found a wide range of values, reflecting glycemic control and metabolic status. To fully understand our patients' health, this information is essential. A significant number of diabetics (39%) had random blood sugar levels indicating poor glycemic control. A large proportion (31%) fell between 200 and 250 mg/dl, raising concerns about diabetes complications.[18] Some patients had even higher blood glucose levels, with 10% exceeding 401 mg/dl. This subgroup needs special attention due to their high risk of acute hyperglycemic events. Diabetes ketoacidosis becomes a major concern when blood sugar levels are high. Thus, these individuals may need increased monitoring and prompt intervention to prevent serious health issues. Hyperglycemia—blood glucose levels above 140 mg/dl (7.8 mmol/l)—has been reported in many non-critically ill hospitalized patients.[18] The blood sugar distribution emphasizes the importance of strict glycemic control in diabetes. This supports scientific evidence that blood sugar regulation prevents microvascular and macrovascular diseases, neuropathy, and retinopathy. The findings suggest improving glycemic control to reduce diabetic risks.

For comprehensive diabetes management, HbA1C is an essential marker for long-term glycemic control.[19] Our study found 56% of patients had HbA1C levels between 6.5% and 8.5% [Table 3]. This range is widely considered the best for glycemic control, indicating that many of our cohorts managed their diabetes well. However, 29% of patients had HbA1C levels between 8.6% and 10.0%. These values indicate poor control and require better management. A total of 11% of smaller patient subsets had HbA1C levels between 10.6% and 12.5%, and 4% exceeded 12.5%. These people may be at higher risk for diabetes complications and benefit from more intensive glycemic control interventions.[19]

Our study examined the relationship between diabetes duration and the QTc interval [Table 4], a cardiac health indicator. Su *et al.*[20] found that patients with diabetes for up to 10 years had similar QTc intervals, indicating stable cardiac health. However, QTc interval prolongation increased from 11 to 20 years of diabetes. This suggests that cardiac health may change as diabetes progresses, requiring closer monitoring. The QTc interval stabilized in patients with over 21-year-old diabetes.[21] Despite the small size of this group, this finding suggests a plateau effect in QTc interval prolongation, which could affect diabetes management in the long run. In addition to diabetes duration, HbA1C levels, a marker of long-term glycemic control, were examined and the QTc interval. Lin *et al.*[22] found that well-controlled diabetics (HbA1C 6.5%–8.5%) had shorter QTc intervals. This suggests that glycemic control may help cardiac health. Patients with suboptimal to poor glycemic control (HbA1C above 8.5%) had longer QTc intervals. This highlights the need for better diabetes management to reduce cardiovascular risks from high HbA1C. Our study concludes that diabetes duration, HbA1C levels, and QTc intervals interact to affect cardiac health. The rising trend of non-communicable diseases suggests general primary care providers and family physicians screen high-risk diabetic patients for early prevention and interventions. General primary care providers and family physicians who are the first point of contact with these types of patients should emphasize the need for personalized, comprehensive diabetes management to improve patient outcomes.

Conclusion

In conclusion, our study illuminates several key aspects of DM and QTc prolongation. We found that QTc prolongation is common in diabetics and linked to diabetes duration and glycemic control. With diabetes and rising HbA1C levels, QTc prolongation risk increases significantly. This is caused by acute and chronic physiological changes in diabetics. We found that glucose control, especially avoiding hyperglycemia, is the most important modifiable factor in preventing QTc prolongation. Our study also highlights the increased risk of SCD in diabetics with QTc prolongation, emphasizing the need for vigilant monitoring and tailored interventions. Healthcare providers should also be cautious when prescribing QTc-affecting medications, especially in diabetics. In conclusion, our findings are crucial for DM cardiac health management. Understanding the complexity of QTc prolongation in diabetes helps clinicians make better decisions and treat diabetics better, reducing the risk of adverse cardiovascular events.

Acknowledgments

The authors thank all the participants for their support. We are grateful for the expert help of faculties and also acknowledge critical manuscript reviews by multiple colleagues.

Ethical approval

The study was approved by the Institutional Ethics Committee of RIMS, Ranchi under Memo No. 268 IEC, RIMS, Dt. 13.06.2021.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Sakran N, Graham Y, Pintar T, Yang W, Kassir R, Willigendael EM, *et al.* The many faces of diabetes. Is there a need for re-classification? A narrative review. BMC Endocr Disord 2022;22:9. doi: 10.1186/s12902-021-00927-y.
2. Svane J, Pedersen-Bjergaard U, Tfelt-Hansen J. Diabetes and the risk of sudden cardiac death. Curr Cardiol Rep 2020;22:112.
3. Mozos I, Serban C. The relation between QT interval and T-wave variables in hypertensive patients. J Pharm Bioallied Sci 2011;3:339-44.
4. Veglio M, Giunti S, Stevens LK, Fuller JH, Perin PC, EURODIAB IDDM Complications Study Group. Prevalence of Q-T interval dispersion in type 1 diabetes and its relation with cardiac ischemia: The EURODIAB IDDM complications study group. Diabetes Care 2002;25:702-7.
5. Veglio M, Bruno G, Borra M, Macchia G, Bargero G, D'Errico N, *et al.* Prevalence of increased QT interval duration and dispersion in type 2 diabetic patients and its relationship with coronary heart disease: A population-based cohort. J Intern Med 2002;251:317-24.
6. Cardoso C, Salles G, Bloch K, Deccache W, Siqueira-Filho AG. Clinical determinants of increased QT dispersion in patients with diabetes mellitus. Int J Cardiol 2001;79:253-62.
7. Sawicki PT, Kiwitt S, Bender R, Berger M. The value of QT interval dispersion for identification of total mortality risk in non-insulin-dependent diabetes mellitus. J Intern Med 1998;243:49-56.
8. Brown DW, Giles WH, Greenlund KJ, Valdez R, Croft JB. Impaired fasting glucose, diabetes mellitus, and cardiovascular disease risk factors are associated with prolonged QTc duration. Results from the third national health and nutrition examination survey. J Cardiovasc Risk 2001;8:227-33.
9. Julu P. Vagolytic effect of diabetes mellitus. Brain 1993;116:485-92.
10. Marfella R, Rossi F, Giugliano D. Hyperglycemia and QT interval: time for re-evaluation. Diabetes Nutr Metab 2001;14:63-5.
11. Veglio M, Borra M, Stevens LK, Fuller JH, Perin PC. The relation between QTc interval prolongation and diabetic complications. The EURODIAB IDDM complication study group. Diabetologia 1999;42:68-75.
12. Stern S, Sclarowsky S. The ECG in diabetes mellitus. Circulation 2009;120:1633-6.
13. Rosenbauer J, Neu A, Rothe U, Seufert J, Holl RW. Types of diabetes are not limited to age groups: type 1 diabetes in adults and type 2 diabetes in children and adolescents. J Health Monit 2019;4:29-49.
14. Gisinger T, Azizi Z, Alipour P, Harreiter J, Raparelli V, Kublickiene K, *et al.* Sex and gender aspects in diabetes mellitus: Focus on access to health care and cardiovascular outcomes. Front Public Health 2023;11:1090541. doi: 10.3389/fpubh. 2023.1090541.
15. Banerjee C, Moon YP, Paik MC, Rundek T, Mora-McLaughlin C, Vieira JR, *et al.* Duration of diabetes and risk of ischemic stroke: The Northern Manhattan Study. Stroke 2012;43:1212-7.
16. Aburisheh K, AlKheraiji MF, Alwalan SI, Isnani AC, Rafiullah M, Mujammami M, *et al.* Prevalence of QT prolongation and its risk factors in patients with type 2 diabetes. BMC Endocr Disord 2023;23:50.
17. Rodriguez CJ, Swett K, Agarwal SK, Folsom AR, Fox ER, Loehr LR, *et al.* Systolic blood pressure levels among adults with hypertension and incident cardiovascular events: The atherosclerosis risk in communities study. JAMA Intern Med 2014;174:1252-61.
18. Umpierrez GE, Hellman R, Korytkowski MT, Kosiborod M, Maynard GA, Montori VM, *et al.* Management of hyperglycemia in hospitalized patients in non-critical care setting: an endocrine society clinical practice guideline. J Clin Endocrinol Metab 2012;97:16-38.
19. Bao Y, Gu D. Glycated hemoglobin as a marker for predicting outcomes of patients with stroke (ischemic and hemorrhagic): A systematic review and meta-analysis. Front Neurol 2021;12:642899. doi: 10.3389/fneur.2021.642899.
20. Su JB, Yang XH, Zhang XL, Cai HL, Huang HY, Zhao LH, *et al.* The association of long-term glycaemic variability versus sustained chronic hyperglycaemia with heart rate-corrected QT interval in patients with type 2 diabetes. PloS One 2017;12:e0183055. doi: 10.1371/journal.pone. 0183055.
21. Pertseva NO, Moshenets KI. Definition of the dependence of QTc interval prolongation on glycemic control in patients with type 2 diabetes mellitus. Medicni Perspektivi 2022;27:58-64.
22. Lin N, Zhang H, Li X, Niu Y, Gu H, Lu S, *et al.* The influence of different glucose tolerance on QTc interval: A population-based study. BMC Cardiovasc Disord 2023;23:47. doi: 10.1186/s12872-023-03081-6.