International Journal of Research in Medical Sciences
Baig ATT et al. Int J Res Med Sci. 2025 Oct;13(10):4262-4267
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20253175

Original Research Article

Evaluation of cardiac autonomic dysfunction using electrocardiography in type 2 diabetes mellitus patients: a case-control study

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Received: 27 July 2025
Accepted: 04 November2025

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is associated with a high risk of cardiovascular complications, including cardiac autonomic neuropathy (CAN), which significantly increases morbidity and mortality. Electrocardiography (ECG) offers a non-invasive method to detect cardiac dysautonomia early. This study aimed to evaluate ECG changes in T2DM patients and correlate them with cardiac autonomic dysfunction.
Methods: A cross-sectional observational study was conducted on 50 T2DM patients and 50 age- and gender-matched healthy controls. Standard 12-lead ECG was performed to assess heart rate, RR interval, PR interval, QRS duration, QRS axis, and QTc interval. Cardiac autonomic function was evaluated using heart rate variability (HRV) parameters and clinical autonomic tests. Statistical analysis was performed to compare ECG parameters and prevalence of ischemic and conduction abnormalities between groups.
Results: T2DM patients exhibited significantly higher mean heart rates (86.9±10.81 versus 78.78±11.26 beats/minute; p=0.001), prolonged PR interval (162.40±31.72 versus 138.20±16.98 msec; p=0.001), increased QRS duration (70.98±12.72 versus 65±8.63 msec; p=0.007), and prolonged QTc interval (410.63±43.80 versus 329.20±29.74 msec; p=0.001) compared to controls. Additionally, ischemia (20% versus 4%; p=0.01), infarction (22% versus 6%; p=0.02), and conduction blocks (14% versus 2%; p=0.02) were significantly more prevalent in T2DM patients. HRV analysis indicated reduced autonomic function in the diabetic group.
Conclusions: T2DM is associated with significant ECG abnormalities reflecting cardiac dysautonomia and increased cardiovascular risk. ECG can serve as a valuable tool for early detection of CAN in diabetic patients, enabling timely intervention to reduce adverse outcomes.

Keywords: Cardiac autonomic neuropathy, Cardiac dysautonomia, Electrocardiography, Heart rate variability, QTc prolongation, Type 2 diabetes mellitus

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and relative insulin deficiency, leading to persistent hyperglycemia. Globally, the prevalence of T2DM has increased dramatically, driven by lifestyle changes, urbanization, and an aging population. According to the International Diabetes Federation, over 537 million adults were living with diabetes in 2021, and this number is projected to rise to 783 million by 2045.[1] India alone contributes significantly to this burden, making diabetes a major public health challenge in the region. The complications of T2DM are wide-ranging and affect multiple organ systems, contributing to increased morbidity and mortality. Among these, cardiovascular complications remain the leading cause of death in diabetic patients.[2]

Cardiovascular disease (CVD) in T2DM is often multifactorial, involving accelerated atherosclerosis, microvascular damage, and autonomic nervous system dysfunction. One of the lesser recognized yet critical

complications is diabetic cardiac autonomic neuropathy (CAN), which is a form of cardiac dysautonomia. CAN results from damage to the autonomic nerve fibers that innervate the heart and blood vessels, leading to abnormalities in heart rate control and vascular dynamics.[3] This autonomic imbalance increases the risk of silent myocardial ischemia, arrhythmias, and sudden cardiac death in diabetic patients.[4] Importantly, CAN is often underdiagnosed because it can be asymptomatic in early stages, yet its presence significantly worsens prognosis.

Electrocardiography (ECG) is a simple, non-invasive, and widely available tool that provides valuable information on cardiac electrical activity and autonomic function. Changes in ECG parameters, such as heart rate variability (HRV), QT interval prolongation, and T-wave abnormalities, can reflect autonomic dysfunction and increased cardiac risk.[5] Studies have demonstrated that reduced HRV, which indicates impaired parasympathetic activity, is common in T2DM patients with cardiac dysautonomia.[6] Moreover, prolonged corrected QT interval (QTc) is associated with higher mortality and arrhythmic risk. Thus, ECG serves as an important diagnostic and prognostic tool for detecting CAN in diabetic individuals.[7]

Despite the recognized importance of cardiac autonomic dysfunction in diabetes, its assessment is not routinely performed in clinical practice, especially in resource-limited settings. There remains a need to establish accessible, reliable markers for early detection of CAN to improve patient outcomes. This study aimed to evaluate the electrocardiographic changes in type 2 diabetes patients and to investigate their correlation with cardiac dysautonomia. By identifying ECG abnormalities linked to autonomic dysfunction, the study seeks to contribute to early risk stratification and management strategies in diabetic populations.

METHODS

This was a case control study conducted at the department of general medicine, Al Ameen Medical College and Hospital, Vijayapura for period of 18 months. With anticipated proportion of arrhythmias/conduction abnormalities in type 2 diabetes patients 55% (ref), the study required a sample size of 96 patients and considering the drop out 100 patients were included in the study. The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all participants prior to enrolment. The population was divided into two groups. Cases group- 50 patients with type 2 diabetes mellitus. Control group- 50 age and sex matched controls.

Inclusion criteria

Patients aged between 30 and 70 years. Diagnosed with T2DM for at least one year. Willing to participate and provide informed consent.

Exclusion criteria

Age >60 years, documented CAD/ischemic heart disease, documented valvular heart disease/congenital heart disease, uremia, drugs-any drug which alters the sinus node impulse generation and AV conduction, features of hypo and hyperthyroidism, fever and features suggestive of infections, chronic obstructive pulmonary disease and other chronic lung disorders, Parkinsonism and other movement disorders, dyselectrolytemia.

A complete history was elicited from the patient and detailed clinical examination will be done. All the study population and controls were subjected for thorough physical examination. Blood samples were drawn and subjected to estimation of causal blood glucose and renal function tests.

Autonomic dysfunction was assessed by the following manoeuvres: parasympathetic function- tachycardia in resting ECG, heart rate response to deep breathing (HRBD); sympathetic function- blood pressure response to standing, QTc prolongation.

Electrocardiography (ECG)

A 12-lead ECG was performed on all patients. The ECG were analyzed for: heart rate and rhythm abnormalities, RR interval and PR interval for assessing autonomic regulation; QRS duration and QRS axis to check for conduction delays or blocks; QTc interval (corrected for heart rate) to assess repolarization abnormalities; HR response to deep breathing (HRBD): this measures the variation in RR intervals during inspiration and expiration, which reflects parasympathetic activity; ST-T changes (indicative of ischemia or myocardial infarction) and other abnormalities such as conduction defects (e.g., AV block, bundle branch block).

Statistical analysis

To compare the ECG parameters, HRV, and other relevant data between cases and controls unpaired student t test was used. To compare categorical variables such as ECG abnormalities between the two groups, Chi square was used. A p value <0.05 was considered as significant.

RESULTS

This study investigates the electrocardiographic (ECG) abnormalities associated with cardiac dysautonomia in patients with Type 2 Diabetes Mellitus (T2DM). The ECG parameters such as QTc interval, heart rate variability (HRV), and ST-T changes were compared between diabetics and healthy controls.

The study included 50 T2DM patients and 50 controls with comparable mean ages (44.20±6.58 versus 45.48±7.73 years, p=0.29) and gender distribution (p=0.31). T2DM patients had significantly higher prevalence of smoking

(64.3% versus 35.7%, p=0.01), alcoholism (50% versus 24%, p=0.007), and history of angina pain (42% versus 8%, p=0.001) compared to controls. The mean duration of diabetes among T2DM patients was 9.08±5.97 years. Both supine and standing blood pressure readings were significantly elevated in T2DM patients compared to controls (p=0.001 for both). The results are shown in Table 1.

Table 1: Demographics and clinical characteristic of the study population.

Parameters	Cases (n=50)	Controls (n=50)	P value
Age (in years)	44.20±6.58	45.48±7.73	0.29 NS
Gender (%)			
Male	35 (70)	31 (62)	0.31 NS
Female	15 (30)	19 (38)	
Smoking Habit (%)	27 (64.3)	15 (35.7)	0.01*
Alcoholism (%)	25 (50)	12 (24)	0.007*
History of angina pain, (%)	21 (42)	4 (8)	0.001*
Diabetes duration (mean±SD)	9.08±5.97	-	-
Blood pressure (mmHg) mean±SD			
Supine	130.98±8.58	123.76±8.73	0.001*
Standing	137.46±8.39	130.72±7.90	0.001*

*Significant (Unpaired student t-test)

Table 2: Comparison of ECG related parameters among the study groups.

Parameters	Cases (n=50)	Controls (n=50)	P value
	Mean±SD		
ECG rate (beats/minute)	86.9±10.81	78.78±11.26	0.001*
ECG RR interval (msec)	725.4±121.49	815.4±114.41	0.001*
ECG PR interval (msec)	162.40±31.72	138.20±16.98	0.001*
QRS duration (msec)	70.98±12.72	65±8.63	0.007*
QRS axis (degrees)	26.40±30.54	47.60±27.81	0.001*
QTC interval (msec)	410.63±43.80	329.20±29.74	0.001*

*Significant (unpaired student t-test)

Table 3: Prevalence of cardiovascular abnormalities among the study population.

Parameters	Cases (n=50) (%)	Controls (n=50) (%)	P value
Ischemia (%)	10 (20)	2 (4)	0.01*
Infarction (%)	11 (22)	3 (6)	0.02*
Intraventricular conduction blocks (%)	7 (14)	1(2)	0.02*
Postural drop of SBP	10 (20)	2 (4)	0.02*

*Significant (unpaired student t-test).

The comparison of ECG related parameters among the T2DM and controls was shown in Table 2. T2DM patients showed a significantly higher mean ECG rate of 86.9±10.81 beats/minute compared to 78.78±11.26 beats/minute in controls (p=0.001). The ECG RR interval was significantly shorter in T2DM patients (725.4±121.49 msec) versus controls (815.4±114.41 msec, p=0.001). The PR interval was prolonged in T2DM patients (162.40±31.72 msec) compared to controls (138.20±16.98 msec, p=0.001). QRS duration was also increased in T2DM patients (70.98±12.72 msec) relative to controls (65±8.63 msec, p=0.007). Furthermore, T2DM patients had a significantly lower QRS axis (26.40±30.54 degrees vs. 47.60±27.81 degrees, p=0.001) and prolonged QTc interval (410.63±43.80 msec versus 329.20±29.74 msec, p=0.001).

The prevalence of cardiovascular events among the T2DM patients and controls was shown in Table 3. Among the T2DM patients, ischemia was observed in 20% (10/50) compared to 4% (2/50) in controls (p=0.01). Infarction was present in 22% (11/50) of T2DM patients, significantly higher than 6% (3/50) in controls (p=0.02). Intraventricular conduction blocks occurred in 14% (7/50) of T2DM patients, while only 2% (1/50) of controls showed this abnormality (p=0.02). Postural drop of systolic blood pressure (SBP) was noted in 20% (10/50) of T2DM patients versus 4% (2/50) of controls (p=0.02). These findings indicate a significantly higher prevalence of cardiac conduction and ischemic abnormalities in T2DM patients compared to controls.

DISCUSSION

This study evaluated electrocardiographic parameters and their correlation with cardiac dysautonomia in patients with type 2 diabetes mellitus. Significant differences in ECG findings and autonomic dysfunction markers were observed between T2DM patients and healthy controls. These results highlight the importance of early cardiac assessment in diabetic patients to prevent adverse cardiovascular outcomes.

The age distribution between cases and controls showed no significant difference, as indicated by the p value of 0.94. Both groups had a similar mean age, with the cases averaging 44.20 years and the controls averaging 44.26 years. This suggests that age is not a confounding factor in this study, as both groups are comparable in terms of their age profile. However, in the case of age-wise distribution, the majority of participants in both groups were between the ages of 41-50 years, with 56% in the cases and 50% in the controls. This reflects the typical demographic distribution for type 2 diabetes, which often manifests in middle-aged individuals. The lack of significant difference (p=0.50) between the age groups supports the notion that the cardiac dysautonomia observed is not age-related but rather a consequence of diabetes. Likewise in a study done by John et al the mean age of the diabetic patients was 49.43±6.44 years and it was not significant when compared with the controls 49.53±5.70 years ($p<0.05$).[8] Likewise, in a study done by Prajna et al majority of the diabetic patients with cardiac dysautonomia were in the age category 41-50 years in 56% of the cases.[9]

In the present study there was a male preponderance in both groups. 70% of the cases and 62% of the controls were male. However, the difference was not statistically significant (p=0.39), suggesting that gender does not significantly influence the presence of cardiac dysautonomia in this study population. In a study done by Inapakolla et al male preponderance was observed in which 54% were males.[10]

The study found a significantly higher prevalence of smoking (64.3% in cases vs. 35.7% in controls) with a p value of 0.01. This suggests that smoking might be a contributing factor to the increased risk of cardiac dysautonomia in diabetic patients. Smoking is known to induce oxidative stress and inflammation, which could exacerbate autonomic dysfunction.

Similarly, the history of alcoholism was also significantly higher in the cases (50% versus 24%) with a p value of 0.007. Alcohol abuse has been linked to various cardiovascular issues, including autonomic dysfunction, which could further worsen cardiac health in T2DM patients.

A key finding in this study was the higher prevalence of angina in diabetic patients (42% versus 8%) with a p value of 0.007. Angina, often a result of coronary artery disease, is a common complication of T2DM due to the increased risk of atherosclerosis. The increased prevalence of angina in the T2DM group highlights the coexistence of cardiac ischemia and autonomic dysfunction, making early detection crucial for preventing further cardiovascular events.

The duration of diabetes was also a critical factor assessed in the study. The mean duration of diabetes among the cases was 9.08 years, with the majority of patients having diabetes for more than 5 years. In a study done by Prajna et al 56% of the patients had diabetes duration less than 5 years, 28% had diabetes duration 6-10 years respectively.[9] In another study done by Prasad et al 50% of the patients had diabetes duration between 2-5 years.[11]

One of the most significant findings in the study was the elevated heart rate (ECG rate) in the T2DM cases (86.9 bpm) compared to the controls (78.78 bpm), with a p value of 0.001. This increased heart rate is a reflection of sympathetic overactivity, a hallmark of cardiac autonomic dysfunction in diabetic patients.[12] In a study done by Prejna et al the mean resting heart rate was higher in diabetics as compared to non-diabetics (84.2±12.86 bpm versus 75.2±10.65 bpm; $p<0.05$).[9]

Another notable finding in the study was the significant reduction in the RR interval in the T2DM patients (725.4 msec) compared to the controls (815.4 msec), with a p value of 0.001. The RR interval represents the time between successive R-wave peaks in the ECG, which correlates with the heart rate. A shorter RR interval indicates an increase in heart rate, which is consistent with the elevated ECG rate observed in T2DM patients.[13]

More importantly, the RR interval is also a surrogate marker for heart rate variability (HRV), which reflects the balance between the sympathetic and parasympathetic nervous systems.[14] A shortened RR interval suggests impaired parasympathetic activity. The parasympathetic nervous system plays a critical role in modulating heart rate variability, especially during periods of rest. The reduced parasympathetic tone in T2DM patients indicates the presence of cardiac autonomic dysfunction.[15] A decrease in HRV is associated with increased sympathetic dominance and reduced autonomic flexibility, which can predispose patients to adverse cardiovascular events, including arrhythmias and heart failure.

The study also revealed a significant increase in the PR interval in diabetic patients (162.40 msec) compared to controls (138.20 msec), with a p value of 0.001. Likewise in a study done by Prasad et al, PR interval was prolonged in diabetics as compared to control (162.4±11.67 versus 138.2±16.99 msec; p=0.001).[11]

In T2DM, autonomic neuropathy can affect the conduction system of the heart, leading to slower transmission of electrical impulses through the AV node, resulting in a longer PR interval.[16]

The study also found that the QRS duration was significantly longer in the T2DM patients (70.98 msec) compared to the controls (65.00 msec), with a p value of 0.001. In a study done by Prajna et al the QRS was prolonged in diabetics when compared to the controls (68.4±11.67 msec versus 65±8.69 msec).[9] In T2DM, diabetic cardiomyopathy and autonomic dysfunction can lead to structural and electrical changes in the heart, including the thickening of the ventricular walls and delayed conduction.[17]

The QRS axis was significantly lower in the T2DM patients (26.40 degrees) compared to the controls (47.60 degrees), with a p-value of 0.001. Likewise in Prasad et al study the QRS axis was lower in diabetics as compared to control (26.4±30.54 versus 67.6±27.82 degrees; p<0.001).[11] The QRS axis represents the overall direction of the electrical impulses during ventricular depolarization. In T2DM patients, the presence of conduction disturbances due to diabetic neuropathy can lead to an altered QRS axis.[18]

The study also found that the QTc interval was significantly prolonged in the T2DM patients (410.63 msec) compared to the controls (329.20 msec), with a p value of 0.001. In a study done by Prasad et al the QTC interval was prolonged in diabetics when compared to controls (405.16±40.38 versus 365.38±25.3 msec; p=0.0001).[11] In T2DM, prolonged QTc intervals are often associated with impaired repolarization, which can lead to arrhythmias such as torsades de pointes, a potentially life-threatening condition.[19]

The study highlighted a significantly higher prevalence of ischemia and myocardial infarction in type 2 diabetes mellitus (T2DM) patients when compared to healthy controls. Specifically, ischemia was found in 20% of diabetic cases versus 4% of controls (p=0.01), and myocardial infarction was observed in 22% of diabetic patients compared to 6% in controls (p=0.02). These findings underscore the increased cardiovascular risk in T2DM, potentially due to factors such as vascular damage, increased oxidative stress, and autonomic dysfunction. Chronic hyperglycemia in T2DM can contribute to endothelial dysfunction, which in turn increases the risk of atherosclerosis and coronary artery disease (CAD). The presence of ischemia and infarction in diabetic patients suggests that early detection and management of ischemic events are critical to preventing further cardiac complications such as heart failure or sudden cardiac death. Regular monitoring of cardiac function through ECG, blood tests, and imaging techniques can help in early identification of ischemic episodes and prompt intervention.

In addition to ischemic events, the study also found a higher prevalence of intraventricular conduction blocks and postural hypotension in diabetic cases. Intraventricular conduction blocks were observed in 14% of T2DM patients, compared to only 2% in the controls (p=0.02). Similarly, postural hypotension, defined as a systolic blood pressure drop of greater than 30 mmHg upon standing, was found in 20% of diabetic patients versus 4% in controls (p=0.02). These findings suggest that T2DM patients may have impaired autonomic regulation, which is responsible for maintaining cardiovascular homeostasis. In healthy individuals, the autonomic nervous system (ANS) helps to adjust blood pressure during position changes, such as from lying down to standing. However, in cardiac autonomic dysfunction, such as in T2DM, this adjustment becomes less effective, leading to postural hypotension. This condition is associated with an increased risk of syncope, falls, and cardiovascular morbidity. Moreover, intraventricular conduction blocks point to a delay in ventricular depolarization, which can impair heart function and increase the risk of arrhythmias and sudden cardiac arrest.

This study is limited by its cross-sectional design, which prevents establishing causal relationships between diabetes duration and cardiac dysautonomia. Additionally, the sample is drawn from a single hospital, which may not be representative of the broader diabetic population, potentially affecting the generalizability of the findings.

CONCLUSION

This study demonstrates that type 2 diabetes mellitus is associated with significant alterations in electrocardiographic parameters indicative of cardiac dysautonomia. T2DM patients show increased risk of ischemic changes, conduction abnormalities, and autonomic dysfunction. Early detection through ECG can aid in timely intervention to reduce cardiovascular complications. Routine cardiac monitoring should be emphasized in the management of diabetic patients.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Baig ATT, Mahishale GS, Kumar MV. Evaluation of cardiac autonomic dysfunction using electrocardiography in type 2 diabetes mellitus patients: a case-control study. Int J Res Med Sci 2025;13:4262-7.