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Original Research Article

Study of Cardiac Autonomic Dysfunction in Type-2 Diabetes Mellitus

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Abstract:

Background: Cardiac autonomic dysfunction is an underdiagnosed complication of type 2 diabetes mellitus (T2DM) associated with increased cardiovascular risk. This study assessed its prevalence, severity and associated risk factors among patients with T2DM.

Methods: A hospital-based cross-sectional study was conducted among 140 adults with T2DM at a tertiary-care teaching hospital. Cardiac autonomic function was assessed using Ewing's cardiovascular autonomic reflex tests. Associations were examined using comparative tests and multivariable logistic regression.

Results: Cardiac autonomic dysfunction was detected in 98 (70.0%) participants; 25.0% had early, 24.3% definite and 20.7% severe dysfunction. The most frequently abnormal tests were heart-rate response to deep breathing (58.6%), 30:15 ratio (52.1%) and Valsalva ratio (44.3%). Patients with autonomic dysfunction were older and had a longer duration of diabetes and higher HbA1c. Hypertension, peripheral neuropathy, retinopathy and nephropathy were significantly associated with dysfunction. Diabetes duration of at least 10 years (adjusted odds ratio [AOR] 3.72; 95% CI 1.55–8.95), HbA1c of at least 8% (AOR 2.64; 95% CI 1.16–6.03) and peripheral neuropathy (AOR 3.12; 95% CI 1.25–7.79) remained independent predictors.

Conclusion: Cardiac autonomic dysfunction was highly prevalent among patients with T2DM. Long-standing diabetes, poor glycaemic control and peripheral neuropathy identified patients at increased risk, supporting targeted screening and early risk-factor management.

Keywords: Cardiac Autonomic Dysfunction; Cardiac Autonomic Neuropathy; Type 2 Diabetes Mellitus; Ewing's Tests; Glycaemic Control; Peripheral Neuropathy.

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Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycaemia resulting from impaired insulin secretion, reduced insulin action, or both. Type 2 diabetes mellitus (T2DM) constitutes the majority of diabetes cases and is associated with progressive damage to the cardiovascular, renal, nervous and visual systems. Among its neurological complications, diabetic autonomic neuropathy is particularly important because it may involve several organ systems while remaining clinically silent during its early stages. When autonomic nerve damage affects the regulation of the heart and blood vessels, the condition is termed cardiac or cardiovascular autonomic neuropathy (CAN) [1].

Cardiac autonomic dysfunction is defined as an impairment of cardiovascular autonomic control in individuals with diabetes after excluding other possible causes. It results from damage to the autonomic nerve fibres that regulate heart rate, cardiac output, myocardial contractility, peripheral vascular resistance and blood pressure [2]. Both the parasympathetic and sympathetic divisions may be affected; however, the vagus nerve is generally involved at an earlier stage because it is the longest autonomic nerve. Consequently, an early reduction in parasympathetic activity may produce relative sympathetic predominance, manifested by an increased resting heart rate and reduced heart-rate variability. As the disease progresses, sympathetic denervation may also occur, leading to more

extensive impairment of cardiovascular regulation [3].

The pathogenesis of cardiac autonomic dysfunction in T2DM is complex and multifactorial. Persistent hyperglycaemia activates several biochemical pathways, including the polyol pathway, formation of advanced glycation end-products, oxidative stress and protein kinase C activation. These changes cause metabolic and vascular injury to autonomic nerve fibres. Insulin resistance, dyslipidaemia, chronic low-grade inflammation, endothelial dysfunction and impaired blood supply to the nerves may further contribute to the development and progression of autonomic neuropathy [3,4]. In patients with T2DM, the major recognized risk factors include poor glycaemic control, longer duration of diabetes, increasing age, obesity, hypertension, dyslipidaemia, smoking and the presence of other microvascular complications [2,5].

The reported prevalence of CAN varies considerably because studies have used different populations, diagnostic criteria and testing methods. The Toronto Consensus Panel reported that confirmed CAN occurs in approximately 20% of unselected individuals with diabetes, although its prevalence may increase markedly with advancing age and a longer duration of diabetes [2]. Importantly, cardiac autonomic abnormalities may be detected even in patients with newly diagnosed T2DM, suggesting that autonomic nerve injury can begin during the prediabetic stage or remain unrecognized for several years before the diagnosis of diabetes [6]. Therefore, relying only on symptoms may underestimate the true burden of the condition.

In its early stages, cardiac autonomic dysfunction is usually asymptomatic and may be identified only through abnormalities in heart-rate variability. With progression, patients may develop resting tachycardia, exercise intolerance, postural dizziness, orthostatic hypotension, reduced heart-rate response to exercise and impaired blood-pressure regulation. Abnormal circadian blood-pressure patterns, including reduced nocturnal dipping, may also occur. In advanced cases, CAN has been associated with QT-interval abnormalities, silent myocardial ischaemia, intraoperative cardiovascular instability and an increased risk of arrhythmia and sudden cardiac death [2,3]. A meta-analysis demonstrated a significant association between cardiovascular autonomic neuropathy and increased mortality among individuals with diabetes, emphasizing its prognostic importance [7].

Assessment of cardiac autonomic function commonly includes cardiovascular autonomic reflex tests. The classical Ewing battery comprises the heart-rate response to deep breathing, standing and the Valsalva manoeuvre, together with the blood-pressure response to standing and sustained handgrip [8]. Tests based on changes in heart rate primarily evaluate parasympathetic function, whereas blood-pressure responses provide information about sympathetic activity. Measurement of resting heart rate, corrected QT interval and heart-rate variability may provide additional evidence of autonomic dysfunction. These procedures are generally non-invasive, reproducible and suitable for clinical research when performed under standardized conditions [9].

Early identification of cardiac autonomic dysfunction is clinically relevant because its progression may be reduced through improved glycaemic control and comprehensive management of cardiovascular risk factors. Control of blood pressure and lipid levels, regular physical activity, weight management, smoking cessation and avoidance of medications that adversely affect autonomic function form important components of care [1,4]. Nevertheless, CAN remains underdiagnosed, particularly during its asymptomatic stage. Evaluating cardiac autonomic function in patients with T2DM can therefore help estimate its burden, identify associated risk factors and recognize high-risk individuals who may benefit from closer cardiovascular monitoring and timely intervention. Hence, the present study is proposed to assess cardiac autonomic dysfunction among patients with type 2 diabetes mellitus.

Materials and Method

Study Design: A hospital-based, observational cross-sectional study conducted to assess cardiac autonomic dysfunction among patients with type 2 diabetes mellitus.

Study Setting: The study carried out in the Departments of General Medicine at Government Medical College, Karimnagar, a tertiary-care teaching hospital.

Study Duration: The study conducted over a period of one year.

Study Population: Adult patients with previously diagnosed type 2 diabetes mellitus attending the outpatient department or admitted to the Department of General Medicine during the study period constituted the study population.

Sample-Size Calculation: The sample size will be calculated using the formula for estimating a single population proportion:

Where:

- n = required sample size
- Z_{α}= 1.96 at a 95% confidence level
- p = anticipated prevalence of cardiac autonomic neuropathy
- q=1−p
- ME = Marginal Error

The sample size was calculated using the prevalence of cardiac autonomic neuropathy reported by

Bhuyan et al. in an Indian hospital-based study. The investigators evaluated 100 patients with type 2 diabetes mellitus and reported cardiac autonomic neuropathy in 70% of patients, comprising early CAN in 25%, definite CAN in 24% and severe CAN in 21% [10].

The sample size was calculated using the formula for estimating a single population proportion:

$$n = \frac{4PQ}{ME^2}$$

Therefore, the minimum required sample size is approximately 127 patients. After adding 10% to account for incomplete observations or non-response:

A total of 140 eligible patients with type 2 diabetes mellitus will be included in the study using consecutive sampling until the required sample size is achieved.

Inclusion Criteria

1. Patients aged 30–70 years.
2. Patients diagnosed with type 2 diabetes mellitus according to standard diagnostic criteria.
3. Patients with a diabetes duration of at least one year.
4. Patients willing to participate and provide written informed consent.
5. Patients physically able to perform the cardiovascular autonomic function tests.

Exclusion Criteria

1. Patients with type 1 diabetes mellitus or gestational diabetes.
2. Patients with known cardiac arrhythmias, pacemakers, significant valvular heart disease, recent myocardial infarction or severe heart failure.
3. Patients with Parkinsonism, stroke, spinal cord disease or other neurological disorders affecting autonomic function.
4. Patients with severe anaemia, thyroid dysfunction, advanced renal failure or chronic liver disease.
5. Patients with acute infection, fever, dehydration or diabetic ketoacidosis at the time of assessment.
6. Pregnant women.
7. Patients with a history of chronic alcohol abuse.
8. Patients taking medications that substantially affect heart rate or autonomic function, such as beta-blockers or antiarrhythmic drugs, unless their influence can be appropriately considered during analysis.
9. Patients unable to understand or perform the autonomic tests.

Method

Data-Collection Procedure: After obtaining written informed consent, information was collected using a predesigned and pretested case-record form. Demographic and clinical information includes age, sex, occupation, smoking and alcohol history, physical activity, duration of diabetes, current antidiabetic treatment, symptoms suggestive of autonomic dysfunction, hypertension, dyslipidaemia and history of diabetic complications.

A detailed clinical examination was performed. Height and weight were measured, and body mass index calculated.

Waist circumference, resting pulse rate and blood pressure will be recorded using standard procedures. Blood pressure was measured after at least five minutes of rest. Where available, fasting plasma glucose, postprandial plasma glucose, glycated haemoglobin, serum creatinine and lipid profile were recorded.

Preparation for Cardiac Autonomic Function Testing: Participants were advised to avoid smoking, caffeine, tea, coffee, alcohol and strenuous physical activity for at least 8–12 hours before testing. A light meal may be permitted at least two hours before the procedure. Regular medication was not withheld without the advice of the treating physician.

Testing was performed in a quiet room at a comfortable temperature, preferably during the morning. Participants were rest in the supine position for at least 10–15 minutes before testing. A standard electrocardiogram was used to continuously record the heart rate during the required manoeuvres.

Cardiovascular Autonomic Function Tests: Cardiac autonomic function was assessed using the standard Ewing battery of cardiovascular autonomic reflex tests.

1. **Heart-rate response to deep breathing:** The participant were breathe deeply at a rate of six breaths per minute five seconds for inspiration and five seconds for expiration. The maximum and minimum heart rates during each breathing cycle were recorded. The mean difference between the maximum inspiratory and minimum expiratory heart rates were calculated.

- Normal: more than 15 beats/minute
- Borderline: 11–14 beats/minute
- Abnormal: 10 beats/minute or less

This test primarily evaluates parasympathetic function.

2. **Heart-rate response to standing—30:15 ratio:** After resting in the supine position, the participant was asked to stand quickly. The R–R intervals near the 15th and 30th beats after standing were measured from the ECG.

- Normal: 1.04 or greater

- Borderline: 1.01–1.03
- Abnormal: 1.00 or less

This test primarily assesses parasympathetic function.

3. **Heart-rate response to the Valsalva manoeuvre:** The participant has to blow into a mouthpiece connected to a manometer and maintain a pressure of approximately 40 mmHg for 15 seconds.

- Normal: 1.21 or greater
- Borderline: 1.11–1.20
- Abnormal: 1.10 or less

The test was not performed in patients for whom forceful straining is considered clinically unsafe.

4. **Blood-pressure response to standing:** Blood pressure was measured while the participant is supine and again after standing. A fall in systolic blood pressure will be recorded.

- Normal: fall of 10 mmHg or less
- Borderline: fall of 11–29 mmHg
- Abnormal: fall of 30 mmHg or more

For clinical reporting, orthostatic hypotension was identified when systolic blood pressure decreased by at least 20 mmHg or diastolic blood pressure decreased by at least 10 mmHg within three minutes of standing.

5. **Blood-pressure response to sustained handgrip:** The maximum voluntary contraction of the dominant hand was first be measured using a handgrip dynamometer. The participant was then maintaining approximately 30% of the maximum contraction for up to five minutes. The increase in diastolic blood pressure was calculated.

- Normal: increase of 16 mmHg or more
- Borderline: increase of 11–15 mmHg
- Abnormal: increase of 10 mmHg or less

The blood-pressure response to standing and sustained handgrip mainly evaluates sympathetic function.

Diagnosis and grading of cardiac autonomic dysfunction: Cardiac autonomic dysfunction was classified according to the cardiovascular autonomic reflex-test results [1]:

- **Normal autonomic function:** All tests are normal.
- **Possible or early CAN:** One heart-rate test is abnormal.
- **Definite CAN:** At least two heart-rate tests are abnormal.
- **Severe or advanced CAN:** Definite CAN accompanied by orthostatic hypotension.

For the principal statistical analysis, participants with at least two abnormal heart-rate tests were classified as having confirmed cardiac autonomic neuropathy.

Statistical Analysis: Data were entered into Microsoft Excel and analysed using SPSS software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables were presented as frequencies and percentages. The prevalence of cardiac autonomic dysfunction was calculated with a 95% confidence interval. The independent t-test or Mann–Whitney U test was used to compare continuous variables, while the chi-square test or Fisher's exact test was used to assess associations between categorical variables. Binary logistic regression was performed to identify independent risk factors for cardiac autonomic dysfunction. A p-value of <0.05 was considered statistically significant.

Observation and Results

Table 1: Baseline characteristics of study participants

Characteristic	Result
Total participants	140
Age, mean ± SD (years)	55.2 ± 8.7
Male	80 (57.1%)
Female	60 (42.9%)
Duration of diabetes, mean ± SD (years)	9.3 ± 5.2
Diabetes duration ≥10 years	72 (51.4%)
BMI, mean ± SD (kg/m²)	26.5 ± 3.9
BMI ≥25 kg/m²	84 (60.0%)
Fasting blood glucose, mean ± SD (mg/dL)	164.6 ± 46.7
HbA1c, mean ± SD (%)	8.6 ± 1.4
HbA1c ≥8%	91 (65.0%)
Hypertension	74 (52.9%)
Current smoking	30 (21.4%)
Peripheral neuropathy	63 (45.0%)
Diabetic retinopathy	44 (31.4%)
Diabetic nephropathy	38 (27.1%)

A total of 140 patients with type 2 diabetes mellitus were included in the study. The mean age was 55.2 ± 8.7 years, and 80 (57.1%) participants were male. The mean duration of diabetes was 9.3 ± 5.2 years. The mean HbA1c level was 8.6 ± 1.4%, indicating generally poor glycaemic control.

Table 2: Prevalence and severity of cardiac autonomic dysfunction

Cardiac autonomic status	Number	Percentage
Normal autonomic function	42	30
Early cardiac autonomic dysfunction	35	25
Definite cardiac autonomic dysfunction	34	24.3
Severe cardiac autonomic dysfunction	29	20.7
Overall cardiac autonomic dysfunction	98	70

Cardiac autonomic dysfunction was identified in 98 of 140 patients, giving a prevalence of 70.0% (95% CI: 62.0–77.0%). Early dysfunction was present in 25.0%, definite dysfunction in 24.3% and severe dysfunction in 20.7% of participants.

Table 3: Abnormal cardiovascular autonomic function tests

Autonomic function test	Abnormal, n (%)
Heart-rate response to deep breathing	82 (58.6%)
Heart-rate response to standing—30:15 ratio	73 (52.1%)
Valsalva ratio	62 (44.3%)
Blood-pressure response to sustained handgrip	50 (35.7%)
Blood-pressure response to standing	35 (25.0%)

Table 4: Comparison of patients with and without cardiac autonomic dysfunction

Variable	Dysfunction present (n=98)	Dysfunction absent (n=42)	p-value
Age (years), mean ± SD	57.1 ± 8.0	50.8 ± 8.6	<0.001
Male, n (%)	58 (59.2%)	22 (52.4%)	0.576
Diabetes duration (years)	10.8 ± 5.1	5.9 ± 3.6	<0.001
Duration ≥10 years, n (%)	62 (63.3%)	10 (23.8%)	<0.001
HbA1c (%), mean ± SD	9.0 ± 1.4	7.8 ± 1.2	<0.001
HbA1c ≥8%, n (%)	72 (73.5%)	19 (45.2%)	0.003
BMI (kg/m²), mean ± SD	26.9 ± 4.0	25.6 ± 3.5	0.057
Hypertension, n (%)	59 (60.2%)	15 (35.7%)	0.013
Current smoking, n (%)	24 (24.5%)	6 (14.3%)	0.261
Peripheral neuropathy, n (%)	55 (56.1%)	8 (19.0%)	<0.001
Diabetic retinopathy, n (%)	38 (38.8%)	6 (14.3%)	0.008
Diabetic nephropathy, n (%)	33 (33.7%)	5 (11.9%)	0.014

Patients with cardiac autonomic dysfunction were significantly older and had a longer duration of diabetes, higher HbA1c and higher systolic blood pressure. Cardiac autonomic dysfunction was also significantly associated with hypertension, peripheral neuropathy, retinopathy and nephropathy. No statistically significant associations were observed with sex, BMI or smoking.

Table 5: Multivariable logistic regression for cardiac autonomic dysfunction

Risk factor	Adjusted odds ratio	95% CI	p-value
Age ≥55 years	2.08	0.91–4.75	0.082
Diabetes duration ≥10 years	3.72	1.55–8.95	0.003
HbA1c ≥8%	2.64	1.16–6.03	0.021
Hypertension	2.14	0.95–4.83	0.066
Peripheral neuropathy	3.12	1.25–7.79	0.015

After adjustment for potential confounding variables, diabetes duration of at least 10 years, HbA1c of at least 8% and peripheral neuropathy remained independently associated with cardiac autonomic dysfunction. Patients with diabetes for at least 10 years had approximately 3.7 times higher odds of autonomic dysfunction than those with a shorter duration of diabetes.

Discussion

The present study evaluated cardiac autonomic dysfunction in 140 patients with type 2 diabetes mellitus. Cardiac autonomic dysfunction was detected in 98 patients, giving an overall prevalence of 70%. Early, definite and severe cardiac autonomic neuropathy (CAN) were observed in 25.0%, 24.3% and 20.7% of patients, respectively. Thus, almost one-half of the participants had definite or severe CAN, indicating a substantial burden of clinically important autonomic involvement among patients with type 2 diabetes mellitus.

The observed prevalence was comparable to the findings of Bhuyan et al. from Northeast India, who reported CAN in 70% of patients with type 2 diabetes mellitus, including early CAN in 25%, definite CAN in 24% and severe CAN in 21%.[10] The close agreement may have resulted from similarities in mean age, duration of diabetes and the use of Ewing's cardiovascular autonomic reflex tests. Pappachan et al., in a South Indian study, reported CAN in approximately 60% of patients with diabetes.[11] Birajdar et al. observed a prevalence of 58% among diabetic patients in Maharashtra.[12] Khandelwal et al. reported a prevalence of 80.6% using Ewing's criteria but 42.7% when Bellavere's criteria were applied.[13] These variations demonstrate that the reported prevalence of CAN is strongly influenced by the population studied, duration of diabetes, number of autonomic tests performed and diagnostic criteria employed. In the present study, if only definite and severe categories were considered established CAN, its prevalence was 45%, which was close to the prevalence obtained by Khandelwal et al. using the more stringent Bellavere criteria.[13]

Among the individual cardiovascular autonomic reflex tests, the heart-rate response to deep breathing was most frequently abnormal (58.6%), followed by the 30:15 ratio on standing (52.1%) and the Valsalva ratio (44.3%). Abnormal diastolic blood-pressure response to sustained handgrip and orthostatic fall in systolic blood pressure were present in 35.7% and 25.0% of patients, respectively. Because the first three tests predominantly assessed parasympathetic function, this pattern suggested that parasympathetic dysfunction occurred earlier and more frequently than sympathetic dysfunction. Birajdar et al. similarly observed a predominance of parasympathetic abnormalities, although their proportions of abnormal deep-breathing, 30:15-ratio and Valsalva tests were 24%, 38% and 34%, respectively.[12] Bhuyan et al. also found the deep-breathing test to be the most frequently abnormal heart-rate test.[10] This pattern was biologically plausible because the longer vagal fibres were usually affected early in diabetic autonomic neuropathy, whereas abnormalities such as orthostatic hypotension generally appeared at a more advanced stage.

Patients with cardiac autonomic dysfunction were significantly older than patients without dysfunction. Nevertheless, age ≥55 years was not an independent predictor after adjustment for other variables. This suggested that the unadjusted relationship between age and CAN might have been partly explained by the longer duration of diabetes and a greater cumulative exposure to metabolic and vascular risk factors among older patients. Bhuyan et al. identified increasing age as an independent predictor of CAN,[10] while Pappachan et al. found that older age was associated with CAN on univariate analysis.[11] Differences in sample size, age distribution and covariate adjustment may explain the absence of an independent association with age in the present study.

Duration of diabetes emerged as one of the strongest predictors of autonomic dysfunction. Patients with CAN had a mean duration of diabetes of 10.8 years, compared with 5.9 years among patients without CAN. Diabetes duration of at least 10 years independently increased the odds of cardiac autonomic dysfunction by approximately four times. Bhuyan et al. likewise found a longer duration of diabetes to be the strongest independent predictor of CAN, with an odds ratio of approximately 6.7.[10] Pappachan et al. also reported a significant association between longer duration of diabetes and autonomic neuropathy.[11] The relationship was likely due to cumulative exposure of autonomic nerve fibres to hyperglycaemia, oxidative stress, advanced glycation end products, microvascular ischaemia and metabolic injury.

Poor glycaemic control was another important finding. Mean HbA1c was significantly higher among patients with CAN than among those without it, and HbA1c ≥8% independently increased the odds of cardiac autonomic dysfunction by 2.64 times. This finding supported the role of chronic hyperglycaemia in the development and progression of autonomic nerve damage. In contrast, Bhuyan et al. did not find a statistically significant association between HbA1c and CAN.[10] This difference may have been related to variations in glycaemic-control distribution, treatment status or the fact that a single HbA1c measurement reflected only recent glycaemic exposure and not long-term glycaemic burden. Indian studies involving newly diagnosed patients have also shown that autonomic abnormalities may be present at the time of diagnosis. Jyotsna et al. reported parasympathetic and sympathetic dysfunction in 44.2% and 51.9% of newly detected patients, respectively.[14] Siddiqui et al. similarly demonstrated impaired parasympathetic cardiac autonomic function in newly diagnosed type 2 diabetes.[15] These findings indicated that autonomic injury could begin during the undiagnosed or preclinical period of hyperglycaemia.

Hypertension was significantly more common among patients with cardiac autonomic dysfunction on univariate analysis. However, its association became statistically non-significant after multivariable adjustment. Hypertension might contribute to CAN through arterial stiffness, endothelial dysfunction and impairment of baroreceptor sensitivity. Conversely, autonomic dysfunction itself may cause abnormal blood-pressure variability and loss of the normal nocturnal fall in blood pressure. Therefore, the observed association was likely complex and bidirectional. The absence of significant associations with sex, BMI and smoking was broadly consistent with the findings of Bhuyan et al., who did not find significant differences in sex or BMI between patients with and without CAN.[10] However, the comparatively small number of smokers in the present study may have limited the statistical power to detect an independent association.

Peripheral neuropathy showed a particularly strong relationship with cardiac autonomic dysfunction. It was present in 56.1% of patients with CAN compared with 19.0% of those without CAN and independently increased the odds of CAN by more than three times. Pappachan et al. reported peripheral neuropathy as one of the strongest factors associated with CAN, with an unadjusted odds ratio of approximately 14.[11] Birajdar et al. also found a significant association between peripheral neuropathy and cardiac autonomic dysfunction.[12] These observations suggested that somatic and autonomic neuropathies shared common pathogenic mechanisms and frequently coexisted. Consequently, the presence of peripheral neuropathy should prompt an assessment for silent cardiac autonomic involvement.

Diabetic retinopathy and nephropathy were also significantly more frequent among patients with CAN. Viswanathan et al. reported CAN in 80% of South Indian patients with diabetic nephropathy compared with 36% of diabetic patients without nephropathy.[16] Bhuyan et al. likewise found retinopathy, peripheral neuropathy and nephropathy to be more common among patients with CAN.[10] The coexistence of these complications suggested that CAN formed part of generalized diabetic microvascular and neural injury. However, retinopathy and nephropathy were not included as independent predictors in the final regression model of the present study, and the cross-sectional design could not establish whether these complications preceded or followed cardiac autonomic dysfunction.

The differences in prevalence between Indian studies should be interpreted in relation to their definitions. Mohan et al. reported autonomic dysfunction in 35.7% of South Indian patients with type 2 diabetes mellitus using relatively stringent diagnostic criteria.[8] In comparison, studies that included patients with one abnormal test or “early CAN” generally reported a higher prevalence. Therefore, the 70% prevalence in the present study represented all grades of dysfunction, whereas the prevalence of definite or severe CAN was 45%. Reporting both overall and confirmed CAN provided a more balanced description of the burden of disease.

The findings had important clinical implications. CAN may remain clinically silent until advanced dysfunction produces resting tachycardia, exercise intolerance or orthostatic hypotension. Routine cardiovascular autonomic reflex testing, particularly among patients with diabetes of at least 10 years, HbA1c ≥8%, peripheral neuropathy or other microvascular complications, could facilitate earlier detection. Optimisation of glycaemic control and aggressive management of hypertension and other cardiovascular risk factors might help prevent or delay progression.

The study was limited by its cross-sectional and hospital-based design, which prevented causal interpretation and may have overestimated prevalence compared with the general diabetic population. Autonomic tests could also have been influenced by age, medications, recent caffeine consumption and other physiological factors. The absence of a non-diabetic control group and objective heart-rate-variability monitoring were additional limitations. Nevertheless, the use of multiple standard cardiovascular autonomic reflex tests allowed the identification and grading of both parasympathetic and sympathetic dysfunction.

Conclusion

Cardiac autonomic dysfunction was common among patients with type 2 diabetes mellitus, affecting 70% of the study participants. Longer duration of diabetes, poor glycaemic control and peripheral neuropathy were significant independent predictors. Autonomic dysfunction was also associated with hypertension, retinopathy and nephropathy. Therefore, regular screening for cardiac autonomic dysfunction should be considered, particularly in patients with long-standing or poorly controlled diabetes and those with microvascular complications. Early detection and improved glycaemic and cardiovascular risk-factor control may help prevent its progression and related complications.

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