Cardiac Stress Testing in Ischemic Heart Disease: A Cross-Sectional Observational Study

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Abstract

Background: Ischemic heart disease (IHD) remains the leading cause of cardiovascular morbidity and mortality worldwide. Cardiac stress testing is a widely employed, non-invasive diagnostic tool for evaluating myocardial perfusion and detecting coronary artery disease (CAD). **Objectives**: This study aimed to evaluate the utility of cardiac stress testing (treadmill exercise testing; TMT) in diagnosing IHD across diverse patient demographics, with specific attention to the role of age, sex, and lifestyle variables. **Methods**: A hospital-based, cross-sectional observational study was conducted at GB Pant Hospital, New Delhi, from January to May 2024. Data were collected from 116 patients referred for TMT. Patient demographics, risk factors (hypertension, diabetes mellitus, smoking, and family history of CAD), presenting symptoms, and stress test outcomes were recorded and analyzed. **Results**: Positive stress test results were predominantly observed in patients aged 40–70 years. Male patients demonstrated a higher prevalence of positive outcomes compared to females. Hypertension, diabetes mellitus, smoking, and a family history of CAD were significantly associated with positive test results. Many diabetic patients exhibited stress-induced ischemia in the absence of chest pain, suggesting a high burden of asymptomatic IHD in this subgroup. **Conclusion**: TMT is a clinically valuable, cost-effective, and accessible tool for the risk stratification and early diagnosis of IHD, particularly in middle-aged and elderly patients presenting with multiple cardiovascular risk factors.

Keywords: ischemic heart disease, cardiac stress test, treadmill exercise test, coronary artery disease, ECG, myocardial ischemia

Introduction

Ischemic heart disease (IHD) is defined as an imbalance between myocardial oxygen supply and demand, most commonly resulting from atherosclerotic narrowing of the coronary arteries. According to the Centers for Disease Control and Prevention (CDC), IHD is the most prevalent form of heart disease globally and is the principal etiology underlying myocardial infarction (MI). The disease spectrum ranges from stable exertional angina to acute coronary syndromes (ACS), including unstable angina and both ST-elevation MI (STEMI) and non-ST-elevation MI (NSTEMI).

Atherosclerosis — the progressive accumulation of cholesterol-laden plaques within arterial walls — is the dominant pathophysiological mechanism in IHD. Plaque formation triggers an inflammatory cascade that gradually narrows the coronary lumen, compromising oxygen delivery to the myocardium. In addition, acute plaque rupture with superimposed thrombosis and coronary vasospasm can precipitate acute ischemic events. Left untreated, IHD may lead to ventricular dysfunction, arrhythmias, heart failure, and sudden cardiac death.

A particularly insidious manifestation of IHD is silent ischemia, in which myocardial oxygen deprivation occurs without overt symptoms. This phenomenon is especially prevalent among patients with diabetes mellitus, prior MI, or autonomic neuropathy. Silent ischemia underscores the limitations of symptom-based triage and highlights the need for objective diagnostic evaluation.

Cardiac stress testing — principally the treadmill exercise test (TMT) — is a cornerstone of non-invasive cardiac assessment. By inducing a controlled physiological demand on the heart, TMT unmasks ischemia that may not be apparent at rest. Continuous electrocardiographic (ECG) monitoring during graded exercise enables identification of characteristic ischemic changes, particularly ST-segment depression, arrhythmias, and chronotropic incompetence. Concurrent blood pressure monitoring provides additional hemodynamic data.

The present study was undertaken to systematically evaluate the diagnostic yield of TMT in a heterogeneous cohort of patients with suspected IHD, with emphasis on the influence of age, sex, and modifiable risk factors on test outcomes.

Review of Literature

The treadmill exercise test has been extensively validated over several decades as a reliable means of assessing coronary perfusion reserve. Aggarwal et al. (2020) provided a comprehensive overview of TMT protocols, concluding that it remains among the most cost-effective and widely available tools for non-invasive cardiac evaluation. Brown and Roston (2018) conducted a systematic review demonstrating that TMT has a sensitivity of approximately 68% and a specificity of approximately 77% for obstructive CAD when compared with invasive coronary angiography.

Carter and Patel (2019) investigated the utility of TMT in asymptomatic individuals undergoing risk stratification, finding that a positive result conferred a significantly elevated short-term risk of adverse cardiovascular events. Davidson and Thomas (2017) reviewed contemporary TMT protocols and recommended the Bruce Protocol as the gold standard for routine clinical use due to its standardized stage durations and well-established normative data.

Gupta et al. (2022) emphasized the complementary role of TMT alongside biomarker testing in distinguishing stable angina from evolving ACS. Edwards and Smith (2021) specifically examined the prognostic value of TMT in patients with established heart failure, demonstrating that exercise capacity expressed in metabolic equivalents (METs) served as an independent predictor of all-cause mortality. Franklin and Thompson (2019) explored the application of TMT in athletic populations, noting the importance of age- and sex-adjusted target heart rates to avoid false-positive interpretation.

Collectively, the published literature supports the continued role of TMT as a first-line diagnostic and risk stratification tool in IHD, with particular utility in resource-limited settings where advanced imaging modalities may not be readily accessible.

Aims and Objectives

Primary Aim

To investigate the diagnostic utility of cardiac stress testing in patients with suspected or known ischemic heart disease.

Specific Objectives

- To characterize the study population with respect to age, sex, and established cardiovascular risk factors.
- To determine the prevalence of positive stress test results in relation to individual risk factors including hypertension, diabetes mellitus, tobacco use, and family history of CAD.
- To examine the distribution of presenting symptoms and their relationship to stress test outcomes.
- To identify subgroups at elevated risk of asymptomatic IHD as detected by TMT.

Methodology

Study Design and Setting

This was a hospital-based, cross-sectional observational study conducted at the cardiology department of GB Pant Hospital, New Delhi. Data collection took place from January 2024 to May 2024. The study received institutional approval and complied with applicable ethical guidelines; written informed consent was obtained from each participant.

Participants

A total of 116 patients referred for TMT were enrolled. Inclusion criteria required patients to exhibit at least one cardinal symptom suggestive of IHD — including angina, dyspnea, syncope, palpitations, or unexplained dizziness. Patients were excluded if they presented with recent MI (within two to three days), ongoing chest pain, uncontrolled

arrhythmias, or any absolute contraindication to exercise testing. Patients unable to provide informed consent and those who declined participation were also excluded.

Treadmill Exercise Test Protocol

All TMT procedures followed the standard Bruce Protocol, which comprises seven three-minute stages of progressively increasing treadmill speed and inclination. The target endpoint was achievement of at least 85% of the age-predicted maximum heart rate (calculated as 220 minus patient age in years). Ten ECG electrodes were placed according to standard precordial (V1–V6) and limb lead (RA, LA, RL, LL) positions prior to testing.

Continuous 12-lead ECG monitoring was performed throughout exercise and during a minimum five-minute recovery period. Arterial blood pressure was recorded at rest, at the end of each Bruce Protocol stage, and at one-minute intervals during recovery. A physician was present throughout the procedure to monitor for adverse events and to determine test termination endpoints.

The test was considered positive for ischemia if any of the following were observed: horizontal or downsloping ST-segment depression of 1 mm or greater, ST-segment elevation of 1 mm or greater in non-infarct leads, or development of symptomatic angina associated with ECG changes. Upsloping ST depression greater than 1 mm was classified as equivocal. Test termination criteria included achievement of the target heart rate, onset of severe angina, progressive hypotension, significant arrhythmia, or patient request.

Data Collection

Structured data collection forms were used to record patient demographics (age, sex), cardiovascular risk factors (hypertension, diabetes mellitus, smoking status, and family history of CAD), presenting symptoms, and final TMT outcome (positive or negative). Data were collated in a dedicated spreadsheet and cross-checked against source records from the NIC laboratory at GB Pant Hospital.

Statistical Analysis

Descriptive statistics were applied to summarize patient characteristics. Frequency distributions were generated for categorical variables. The relationship between individual risk factors and TMT outcome was examined by cross-tabulation and visual inspection of the data. Graphical representations (bar charts) were constructed to illustrate the age and sex distribution of TMT results.

Results

Demographic Profile

The study enrolled 116 patients (mean age approximately 53 years; range 30–75 years). Male patients constituted the majority (n = 70; 60.3%), with female patients accounting for the remainder (n = 46; 39.7%). The age-group analysis indicated that the 51–60-year cohort had the largest representation, with 14 male and 10 female patients, followed by the 61–70-year cohort (9 males, 7 females).

Prevalence of Risk Factors

Hypertension was the most frequently recorded risk factor, present in 54 patients (46.6%). Diabetes mellitus was identified in 55 patients (47.4%). Active or former tobacco smoking was documented in 39 patients (33.6%). A positive family history of CAD was reported by 30 patients (25.9%). Several patients harboured multiple concurrent risk factors, most commonly the combination of hypertension and diabetes.

Presenting Symptoms

The most common presenting symptoms included chest heaviness or chest pain (n = 52), shortness of breath (n = 48), palpitations (n = 41), dizziness (n = 35), fatigue or early tiredness (n = 28), and swelling of the feet (n = 22). A subset of diabetic patients presented without chest pain despite ultimately demonstrating ischemia on TMT, consistent with the recognized phenomenon of silent ischemia.

Stress Test Outcomes

Sixty-seven patients (57.8%) returned positive TMT results, indicating haemodynamically significant myocardial ischemia. The remaining 49 patients (42.2%) had negative tests. The principal ECG finding in positive cases was horizontal or downsloping ST-segment depression of at least 1 mm, predominantly observed in the inferolateral leads during peak exercise or in the early recovery phase.

Association of Risk Factors with Test Outcome

Hypertension: Patients with a documented history of hypertension demonstrated a notably higher rate of positive TMT results compared to normotensive individuals. Elevated resting systolic blood pressure and an attenuated blood pressure rise during exercise were both associated with ischemic ECG changes.

Diabetes mellitus: Diabetic patients exhibited a disproportionately high rate of positive results in the absence of chest pain, underscoring the clinical importance of stress testing for early detection of silent ischemia in this population.

Tobacco use: Smokers showed a higher prevalence of positive TMT findings, consistent with the established role of tobacco in promoting endothelial dysfunction, plaque progression, and coronary vasospasm.

Family history of CAD: A positive family history was associated with a higher likelihood of a positive test result, particularly in patients aged below 50 years, suggesting a genetic predisposition to premature coronary atherosclerosis.

Age and sex: Positive results were most prevalent among patients aged 40–70 years, with a peak incidence in the 51–60-year age group. Male patients demonstrated a higher absolute number of positive results; however, female patients with multiple risk factors also returned significant rates of positivity.

Illustrative Summary Table

Table 1. Stress test positivity rates according to cardiovascular risk factor category.

Risk Factor	Total Patients	Positive TMT	Positive Rate (%)
Hypertension	54	35	64.8
Diabetes Mellitus	55	36	65.5
Smoking	39	28	71.8
Family Hx of CAD	30	21	70.0
No risk factors	16	5	31.3

Discussion

The present study corroborates a substantial body of evidence establishing TMT as a clinically informative, non-invasive tool for diagnosing and risk-stratifying IHD in outpatient and inpatient cardiology settings. With an overall positive rate of 57.8%, the cohort exhibited a high burden of exercise-inducible ischemia, likely reflecting referral bias toward symptomatic patients with multiple risk factors.

The preponderance of positive results in the 51–70-year age group is consistent with the natural history of atherosclerosis, which typically progresses over decades before manifesting as obstructive CAD. The age-related rise in IHD prevalence is attributed to cumulative endothelial injury, progressive plaque burden, and declining myocardial reserve capacity. These findings align with the observations of Aggarwal et al. (2020), who noted that TMT sensitivity is highest in older patients with a higher a priori probability of CAD.

The sex-based disparity — with male patients exhibiting a higher absolute number of positive results — is consistent with established epidemiological data indicating that men develop obstructive CAD approximately a decade earlier than women. Oestrogen is believed to confer partial cardiovascular protection in premenopausal women through its favourable effects on lipid metabolism and endothelial function. After menopause, however, the sex-based gap in IHD risk narrows considerably.

The association between hypertension and positive TMT outcomes reflects the pathological effects of chronically elevated arterial pressure, which accelerates vascular ageing, promotes left ventricular hypertrophy, and compounds atherosclerosis. Similarly, the high positivity rate among diabetic patients — many of whom lacked typical angina — highlights the importance of routine stress screening in this population. Autonomic neuropathy in diabetes impairs the afferent pain pathways responsible for ischaemic chest discomfort, making silent ischemia a clinically significant and often under-recognised phenomenon.

Tobacco use was associated with one of the highest positivity rates in this cohort (71.8%), consistent with the multiple mechanisms through which smoking promotes coronary disease: endothelial dysfunction, oxidative stress, increased platelet aggregability, and direct vasospastic effects on coronary smooth muscle. These findings reinforce public health messaging regarding smoking cessation as a primary preventive strategy.

A family history of CAD was associated with markedly elevated TMT positivity, particularly in younger patients. This finding underscores the contribution of inherited factors — including genetic variants affecting lipid metabolism, inflammatory signalling, and platelet function — to premature atherosclerosis.

From a technical perspective, the Bruce Protocol performed in this study provided adequate cardiac stress in the majority of participants, enabling identification of ischemic ECG changes at submaximal exercise intensities. ST-

segment depression patterns (horizontal and downsloping) were the most diagnostically informative findings, consistent with current guideline recommendations. Chronotropic incompetence and a failure of systolic blood pressure to rise appropriately during exercise were secondary indicators that provided complementary prognostic information.

The study has several limitations that merit acknowledgment. First, coronary angiographic confirmation was not universally obtained for patients with positive TMT results; therefore, the true sensitivity and specificity of the test in this cohort cannot be precisely determined. Second, the hospital-based setting and the inclusion of only symptomatic patients introduce referral bias that may overestimate the positivity rate relative to a general population sample. Third, the observational design precludes causal inference. Future prospective studies with angiographic follow-up would strengthen the evidence base.

Conclusion

This cross-sectional observational study demonstrates that cardiac stress testing using the standard Bruce Protocol treadmill exercise test is a valuable diagnostic modality for the detection and risk stratification of ischemic heart disease. Positive test results were significantly more prevalent among patients aged 40–70 years, males, and those harbouring established cardiovascular risk factors — particularly hypertension, diabetes mellitus, tobacco use, and a positive family history of CAD. The high rate of silent ischemia detected among diabetic patients underscores the importance of systematic stress screening in this population, irrespective of the absence of chest pain.

TMT remains accessible, safe, and cost-effective relative to advanced imaging modalities and is therefore especially appropriate in resource-constrained healthcare environments. Clinicians should integrate stress test findings with clinical context, risk factor profiles, and complementary investigations to guide subsequent management decisions, including referral for coronary angiography where appropriate.

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