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RESEARCH ARTICLE
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EVALUATING THE DIAGNOSTIC ACCURACY OF EXERCISE TOLERANCE TEST IN DETECTING CORONARY ARTERY DISEASE: A STUDY CORRELATING RESULTS WITH ANGIOGRAPHIC FINDINGS AT AYUB TEACHING HOSPITAL, ABBOTTABAD, PAKISTAN"

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ABSTRACT

Background: The exercise tolerance test (ETT) and coronary angiography are widely used diagnostic tools to assess patients with suspected ischemic heart disease. Coronary angiography remains the gold standard for diagnosing coronary artery disease (CAD). This study evaluates the positive predictive value (PPV) of ETT for diagnosing CAD, using coronary angiography as the reference standard.

Methods: This cross-sectional study was conducted at Ayub Teaching Hospital, Abbottabad, Pakistan, from January 15, 2023, to july 25, 2023. A total of 95 patients with positive ETT results were included after applying strict inclusion and exclusion criteria. All patients underwent coronary angiography following their ETT. Data were collected using a structured proforma and analyzed using the Statistical Package for Social Sciences (SPSS), version 23 (IBM Corp., Armonk, NY). The PPV of ETT was calculated across various demographic and clinical parameters.

Results: Among the 95 patients, 77 were male, and 18 were female, with a mean age of 53.3 ± 7.6 years. Of the study population, 35.1% had type-2 diabetes mellitus, and 31.9% were hypertensive. Coronary angiography revealed significant coronary artery occlusion (≥70% stenosis) in 70 patients, while 25 had normal angiographic findings. The overall PPV of ETT for diagnosing CAD was calculated at 73.4%. Subgroup analysis showed that the PPV was higher among males, smokers, diabetics, and non-hypertensive patients, while it was comparatively lower in females, non-smokers, non-diabetics, and hypertensive.

Conclusion: Our findings suggest that a positive ETT result has a notable likelihood of false positivity in certain subsets of the population, particularly females, non-smokers, hypertensive individuals, and non-diabetics. Clinicians should exercise caution when interpreting ETT results in these groups. While coronary angiography provides definitive anatomical information, it does not assess myocardial function under stress. Therefore, further studies integrating non-invasive imaging modalities, such as stress echocardiography or myocardial perfusion imaging, are recommended for a more comprehensive evaluation in these patients.

INTRODUCTION

Coronary artery disease (CAD) is one of the leading causes of morbidity and mortality worldwide, with a particularly significant burden in middle-aged adults. In Pakistan, this condition has become increasingly prevalent due to rising rates of diabetes, hypertension, and smoking. The exercise tolerance test (ETT) is a widely utilized, non-invasive diagnostic tool to assess ischemic cardiac conditions. It involves a series of structured physical

Exercises combined with electrocardiographic monitoring to detect myocardial ischemia[1]. Despite its widespread use as a preliminary test, ETT is known for its relatively high sensitivity but lower specificity due to the influence of various cardiovascular and systemic factors on its outcomes[2].ETT is often used as the first-line investigation in patients with suspected CAD to determine the need for further evaluation, such as referral for coronary angiography. Among the commonly employed protocols for ETT, the Bruce protocol stands out due to its progressive increase in exercise intensity across multiple stages, enhancing its sensitivity for detecting ischemic changes. ETT plays a significant role in diagnosing ischemic heart disease, evaluating exercise-induced angina, assessing cardiopulmonary stability, and identifying high-risk patients who may benefit from advanced diagnostic or therapeutic interventions[3]. However, the test is contraindicated in certain clinical scenarios, including ongoing myocardial infarction, unstable angina, ventricular arrhythmias, and other conditions posing hemodynamic instability. While sensitivity and specificity are widely recognized as key indicators of a diagnostic test's validity, the positive predictive value (PPV) is of greater clinical relevance. PPV reflects the likelihood that patients with a positive test result truly have the disease. This metric is especially critical for clinicians in resource-limited settings, where avoiding unnecessary interventions can significantly reduce the financial and emotional burden on patients and healthcare systems. A high PPV minimizes inappropriate admissions, reduces patient anxiety, and ensures more efficient utilization of healthcare resources[4]. In developing countries like Pakistan, where healthcare systems face unique challenges, the utility and interpretation of ETT may be influenced by factors such as limited access to advanced diagnostic tools, observer bias, and inadequate training. Although ETT is commonly performed, there is a paucity of local data evaluating its PPV against coronary angiography. Most studies in the field have been conducted in specialized centers in developed countries, where healthcare infrastructure and patient demographics differ considerably from those in Pakistan.[5]

This study aims to bridge this knowledge gap by evaluating the PPV of ETT for diagnosing CAD in a tertiary care hospital setting in Pakistan. By identifying factors that influence ETT outcomes in the local population, our research seeks to improve the accuracy of CAD diagnosis and optimize patient care. This will add to the growing body of literature on exercise testing and provide valuable insights for clinicians working in resource-limited settings.

MATERIALS AND METHODS

This cross-sectional study was carried out in the Cardiology Department at AYUB Teaching Hospital, Abbottabad, Pakistan, from January 15, 2023, to July 25, 2023. The study aimed to assess patients who tested positive for inducible angina on the Exercise Tolerance Test (ETT). A total of 214 patients were initially screened, but after applying strict inclusion and exclusion criteria, 95 patients were selected for the final analysis. Patients with a known history of ischemic heart disease, prior coronary angiography, or contraindications to angiography were excluded from the study. Additionally,

individuals who had previously undergone percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), or valvular replacement surgery were also excluded. Other exclusion criteria included patients diagnosed with valvular heart diseases, those with Wolf-Parkinson-White (WPW) syndrome, or individuals with obstructive or restrictive lung diseases. These exclusions were necessary to maintain the homogeneity of the study sample and to ensure that the results were representative of the population under investigation. After applying these stringent criteria, a cohort of 95 patients was identified and included in the final analysis. All eligible participants underwent coronary angiography, and their results were recorded in a standardized data collection form. Informed consent was obtained from each participant, and confidentiality was strictly maintained throughout the study. The sample size was calculated using the OpenEpi sample size calculator, developed by AG Dean, KM Sullivan, and MM Soe. Ethical approval was granted by the Ethical Review Committee of the Medical Teaching Institute (MTI) at AYUB Teaching Hospital. The study's demographic data were tabulated, distinguishing between patients with true-positive and false-positive ETT results. Positive predictive values (PPV) for each demographic variable were calculated. The Chi-square test was employed to determine any significant associations between categorical variables. A p-value of less than 0.05 was considered statistically significant. All data analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 23, ensuring the accuracy and reliability of the results. This study was conducted in full adherence to ethical standards and aimed to provide valuable insights into the predictive accuracy of ETT in patients suspected of having ischemic heart disease in our local context.

RESULTS

This study included a total of 95 patients, comprising 77 males and 18 females, with ages ranging from 27 to 68 years. The cohort had a diverse distribution of cardiovascular risk factors, which included hypertension, diabetes mellitus, and smoking. These factors were prevalent among both male and female participants, reflecting the common risk profile of individuals suspected to have ischemic heart disease in our local setting. The participants were further characterized based on their demographic profiles, which were systematically recorded and analyzed. The baseline characteristics, including age, gender, and the presence of key risk factors, are summarized in Table 1. The distribution of these factors highlights the importance of considering multiple comorbidities in the assessment of patients with suspected coronary artery disease. The study’s findings underline the significant burden of lifestyle-related risk factors in our patient population. Smoking and hypertension, in particular, were observed to be prevalent, which is consistent with existing research on the major contributors to cardiovascular morbidity. Additionally, the presence of diabetes as a contributing factor adds another layer of complexity to the patient management, requiring tailored interventions. The variation in risk factor distribution across different demographic groups in our study further emphasizes the need for a personalized approach to diagnosis and treatment. These findings will guide future research and clinical practices in addressing cardiovascular risk in the local population. The detailed demographic data, along with the analysis of the various risk factors, are provided in Table 1 for further reference.

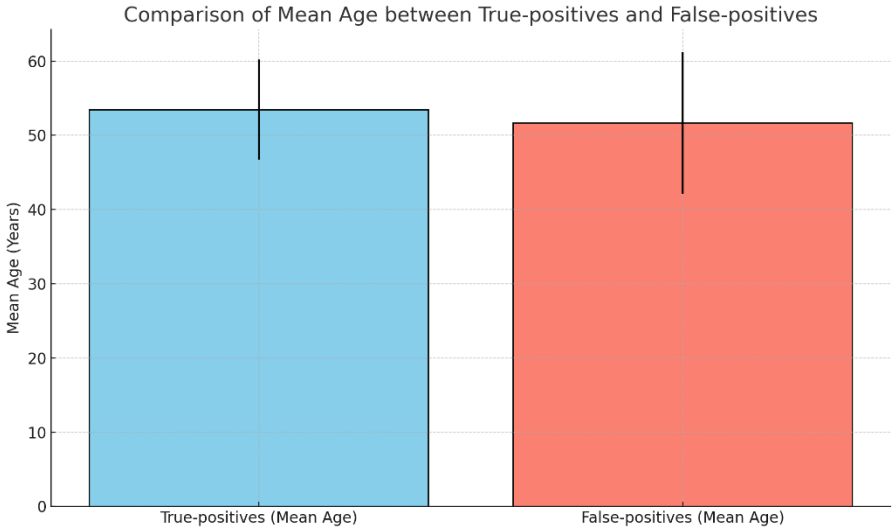
Parameters	Results
Total Patients	95
Age Range	27–68 years
Mean Age	53.28 ± 7.55 years
Gender Distribution	Males: 77(81.85%) Females: 17 (19.15%)
Diabetics	33 (35.1%)
Hypertensive	30 (31.9%)

Smokers	9 (9.57%)
Angiography Results	Normal: 25 (26.6%)
	SVCAD: 34 (36.2%)
	DVCAD: 13 (13.8%)
	TVCAD: 22 (23.4%)
Treatment Offered	Angioplasty: 43 (45.7%)
	CABG: 15 (16%)
	Medical Treatment: 12 (12.8%)
	Reassurance: 24 (25.5%)

TABLE 1: Background characteristics of the study participants.

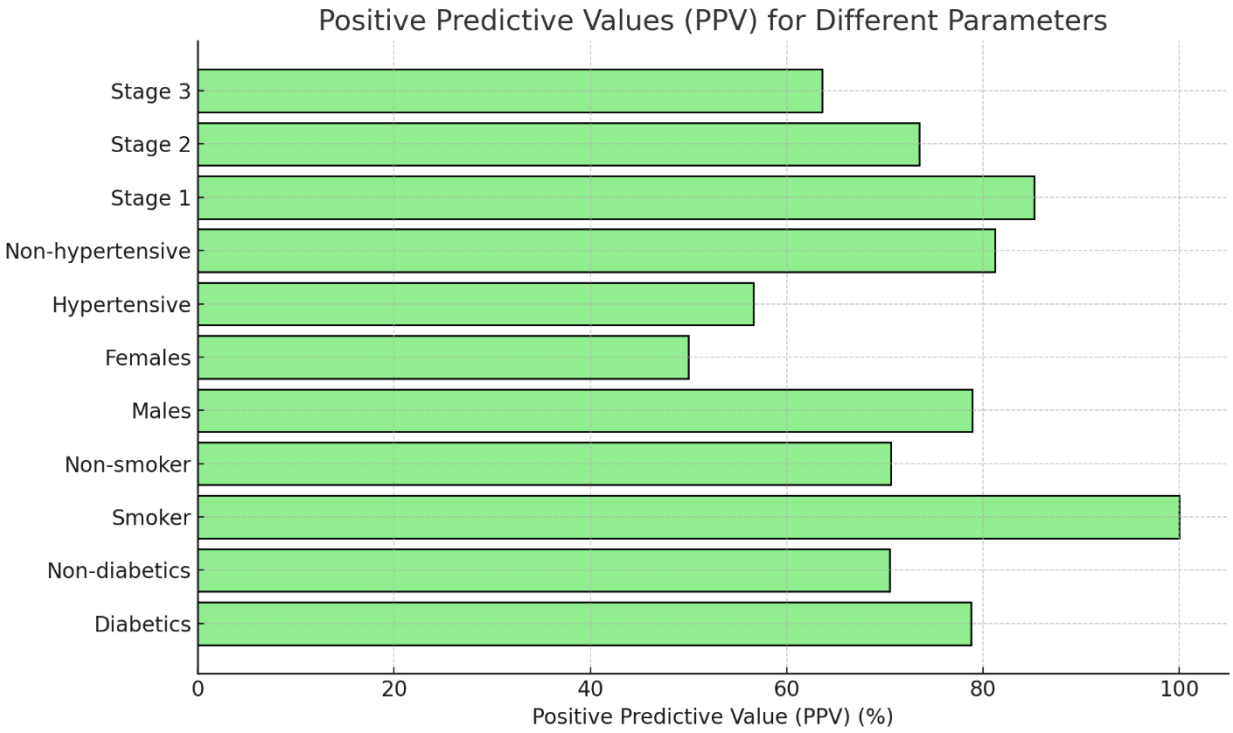
SVCAD: Single-vessel coronary artery disease; DVCAD: double-vessel coronary artery disease; TVCAD: triple-vessel coronary artery disease; CABG: coronary artery bypass grafting.

The mean age of patients with positive ETT and significant vessel occlusion on angiographic evaluation (true-positives) was 53.49 ± 6.75, whereas those with positive ETT and normal angiography (false-positives) were 51.68 ± 9.56. A comparison of true-positives and false-positives concerning baseline characteristics are delineated in chart 1.



Parameters		True-Positive	False-Positive	P Value*
Diabetes	Diabetics	26 (37.7%)	7 (28%)	0.39
	Non-diabetics	43 (62.3%)	18 (72%)	
Smoking Status	Smoker	9 (13.04%)	0 (0%)	0.05
	Non-smoker	60 (86.96%)	25 (100%)	
Gender	Males	60 (87%)	16 (64%)	0.01
	Females	9 (13%)	9 (36%)	
Hypertension	Hypertensive	17 (24.6%)	13 (52%)	0.02
	Non-hypertensive	52 (75.4%)	12 (48%)	
Stage of ETT	Stage 1	23 (33.3%)	4 (16%)	0.17
	Stage 2	25 (36.2%)	9 (36%)	
	Stage 3	21 (30.4%)	12 (48%)	

TABLE 2: Comparison between true-positives and false-positives of ETT.



Parameters		Positive predictive values (PPV)
Diabetes	Diabetics	78.8%
	Non-diabetics	70.5%
Smoking Status	Smoker	100%
	Non-smoker	70.6%
Gender	Males	78.9%
	Females	50%
Hypertension	Hypertensive	56.6%
	Non-hypertensive	81.2%
Stage of ETT	Stage 1	85.2%
	Stage 2	73.5%
	Stage 3	63.6%

TABLE 3: A delineation of positive predictive values of various parameters.

ETT: Exercise tolerance test.

DISCUSSION

The Exercise Tolerance Test (ETT) has long been recognized as a valuable, cost-effective diagnostic tool for evaluating patients with suspected coronary artery disease (CAD). It serves as an initial screening method to assess and rule out myocardial ischemia. In our study, we analyzed the results of angiography in 95 consecutive patients who were initially identified as having inducible angina based on ETT, performed using the Bruce protocol[6]. The literature widely acknowledges the ETT as an effective first-line test, with a reported sensitivity of up to 98%, although its specificity remains a concern, typically reported as lower than desired. The relatively low specificity of the ETT can be attributed to several confounding factors, including metabolic conditions, structural heart abnormalities, conduction disorders, and the use of digitalis therapy.[7] These factors can lead to false-positive results, complicating the interpretation of the test, particularly in settings with a high prevalence of these conditions, such as in developing countries where ETT is often the most accessible

diagnostic option for CAD. In our cohort, we observed that 73.4% of patients with a positive ETT result had abnormal findings on subsequent angiography, consistent with previous studies where the positive predictive value (PPV) of ETT ranged between 75% and 85%. For example, in one study, the PPV of ETT was found to be 78% for patients with a 1.0 to 1.9 mm ST-segment depression and 97% for those with ST-segment depression of 2 mm or greater. The PPV also appears to improve when multiple variables are considered, [10, 11] rather than relying on a single diagnostic criterion. In our analysis, we found that male patients exhibited a significantly higher PPV (78.9%) compared to female patients (50%). This difference, with a statistically significant p-value of 0.01, mirrors findings from a study in Bangladesh, where ETT was found to be more sensitive in males, whereas females were more likely to experience false-positive results[8, 9]. Other studies also suggest that women tend to have a higher risk of false positives on ETT, which has led to the adoption of more invasive diagnostic modalities, such as magnetic resonance imaging (MRI) or radioactive scans, in female patients. These findings highlight the need for careful interpretation of ETT results in women and the potential for further diagnostic evaluation. The low PPV associated with false-positive results significantly affects the clinical utility of ETT[12]. A high number of false positives can lead to unnecessary follow-up procedures, causing increased patient burden, both physically and psychologically, as well as an added economic strain on healthcare systems. This is especially true in developing countries, where resources are limited. As such, the cost-effectiveness and accuracy of ETT must be considered alongside these broader implications. Regarding comorbidities, our study found that diabetic patients had a PPV similar to previous reports, which typically range around 77%. This is consistent with the understanding that diabetes is an established risk factor for the development of more complex forms of CAD. Similarly, chronic smokers in our study demonstrated a higher PPV compared to non-smokers, supporting the known association between smoking and the progression of CAD. The increased likelihood of false-positive results in hypertensive patients is also notable, as they tend to exhibit ST-segment depression due to impaired subendocardial perfusion, which can lead to a higher incidence of false positives. Our findings align with those of other studies, which have reported a lower PPV in hypertensive individuals (around 50%) compared to normotensive individuals (around 88%).In light of these findings, the limited accuracy of ETT in detecting inducible angina has prompted an increased reliance on more invasive imaging techniques, such as myocardial perfusion scans (MPS) or cardiac magnetic resonance imaging (CMR), which offer greater diagnostic precision. However, despite its limitations, ETT remains a valuable tool in the functional assessment of the heart during exercise and stress, particularly in patients with a normal resting ECG.In conclusion, while ETT continues to play a crucial role in the evaluation of CAD, the potential for false-positive results must be carefully managed, particularly in specific patient subgroups. Further research and consideration of alternative diagnostic modalities are warranted to optimize the accuracy and predictive power of CAD screening, especially in resource-limited settings like ours.

CONCLUSIONS

The Exercise Tolerance Test (ETT) remains a valuable tool for the initial evaluation of coronary artery disease (CAD), offering a cost-effective and accessible method for identifying myocardial ischemia. However, our study highlights that while ETT can provide important insights, it is not without limitations. In particular, we found that a positive ETT result carries a considerable risk of false positivity, especially among female patients, non-smokers, and those with hypertension. These findings underscore the importance of considering patient demographics and comorbid conditions when interpreting ETT results. Interestingly, our results suggest that smokers and diabetic patients have a higher positive predictive value (PPV) with ETT, indicating that these groups may benefit from more reliable results in detecting CAD. However, given the potential for false positives, further diagnostic confirmation is often necessary. In light of these challenges, it may be beneficial to integrate advanced diagnostic techniques, such as myocardial perfusion scanning (MPS) or cardiac magnetic resonance imaging (CMR), into the clinical workflow to improve the accuracy of CAD detection. These modalities can provide additional diagnostic clarity, particularly when ETT results

are inconclusive or when the risk of false positives is high. As our understanding of the limitations of ETT grows, a more comprehensive approach, combining various diagnostic tools, will likely lead to better patient outcomes and more efficient use of healthcare resources.

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ADDITIONAL INFORMATION

Approval is here by granted to Dr. Yasir zeb and his team, Resident Physician at Ayub Teaching Hospital Abbottabad, to collect data from ATH,for research titled ‘Evaluating the Diagnostic Accuracy of Exercise Tolerance Test in Detecting Coronary Artery Disease, A Study Correlating Results with Angiographic Findings. During this study, all personal information of subjects were kept confidential.

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Authors Contribution

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Drafting; Waleed Asif Khurshid[3], Uffaq Sandeela[5] Bushra Shaheen [6].

Data Analysis; , Khan Ifrah Shahid [7], Irfan Ullah [8], Talha Ilyas Khan[9], Maria Saleem[10] Waleed Asif Khurshid[3], Uffaq Sandeela[5]

Critical Review: Khan Ifrah Shahid [7], Irfan Ullah [8] Waleed Asif Khurshid[3]

Final Approval of version; Muhammad Abbas Khan [1], Yasir Zeb[4]