International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 24s, 2025
https://theaspd.com/index.php

Integrated Retrospective Assessment Of Biochemical And Cardiovascular Parameters In Coronary Artery Disease Patients And Healthy Individuals In Visakhapatnam

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Abstract

Background: *Coronary artery disease (CAD) is the leading cause of global mortality, accounting for 17.9 million deaths annually. In India, its prevalence continues to rise, with urban regions showing a higher burden compared to rural areas. Visakhapatnam, a rapidly urbanizing coastal city, mirrors this trend, with increasing CAD incidence linked to hypertension, diabetes and dyslipidemia. Biochemical markers such as glucose indices, lipid profile, serum electrolytes, liver function tests, renal function tests and along with cardiovascular assessments including blood pressure, echocardiography, treadmill testing and coronary angiography are essential tools for evaluating CAD risk and disease progression. An integrated assessment of these parameters may strengthen risk identification and support preventive care.*

Aim: *The aim of the present study was to investigate the relationship between biochemical parameters and cardiovascular diagnostic parameters among patients with coronary artery disease and healthy controls, through a retrospective case-control approach in the Visakhapatnam population.*

Methods: *A retrospective study was conducted at Visakhapatnam using Star Pinnacle Heart Centre hospital records of angiographically confirmed CAD patients (n=200) and age, sex matched controls (n=200). Biochemical data included haemoglobin, blood pressure, serum electrolytes, carbohydrate metabolism, lipid metabolism, liver function tests, renal function tests. Cardiovascular parameters like 2D echocardiography and coronary angiography were recorded in patients. Treadmill test (TMT) was conducted in controls. Statistical analysis was performed using SPSS V20.*

Results: *Statistical analysis using the t-test demonstrated a significant difference in haemoglobin levels between the study groups. Parameters related to blood pressure, carbohydrate metabolism and lipid metabolism showed highly significant differences, indicating a strong association with disease status. In contrast, serum electrolytes, liver function tests (LFTs) and renal function tests (RFTs) exhibited no significant variation between the groups. Similarly, chi-square analysis revealed no significant associations for cardiovascular diagnostic findings, including 2D echocardiography, coronary angiography and treadmill test (TMT) results.*

Conclusions: *the present retrospective analysis demonstrates alterations in haemoglobin, blood pressure, glucose regulation and lipid markers are strongly linked with CAD, whereas electrolyte balance, hepatic, renal indices and cardiac diagnostic tests did not differ between groups. These results point to the clinical value of specific biochemical and cardiovascular measures in recognizing individuals vulnerable to CAD and highlight their potential in shaping preventive and therapeutic approaches.*

Keywords: *Coronary artery disease; haemoglobin; blood pressure; lipid metabolism; 2D echocardiography; angiogram; treadmill test.*

INTRODUCTION

Coronary artery disease (CAD) is a leading contributor to morbidity and mortality worldwide, accounting for nearly 17.9 million deaths each year[1]. The burden continues to increase, with CAD representing the most prevalent form of cardiovascular disease and a major cause of healthcare expenditure in both developed and developing nations[2].In India, CAD has emerged as a significant public health challenge, with prevalence rates estimated between 4-5% in rural areas and 8-10% in urban settings[3]. The disease frequently presents at an earlier age compared with Western populations, resulting in higher years of life

lost and escalating clinical and economic impact[4].

Visakhapatnam, a rapidly urbanizing coastal city in Andhra Pradesh, reflects this growing burden. The rising incidence of hypertension, diabetes and dyslipidemia in this region has contributed to an increasing number of CAD cases. However, limited research has explored the role of biochemical and cardiovascular profiles in distinguishing patients with CAD from healthy individuals in this population[5].

Biochemical investigations provide crucial information on metabolic abnormalities associated with CAD. Parameters such as fasting, postprandial blood glucose, HbA1c, lipid profile (total cholesterol, triglycerides, LDL, HDL), serum electrolytes, liver function tests and renal function tests are routinely used to assess systemic alterations contributing to disease progression[6].

Cardiovascular evaluations complement these findings by assessing structural and functional changes in the heart. Measurements including blood pressure, two-dimensional echocardiography (2D-ECHO), treadmill testing (TMT) and coronary angiography are critical for diagnosing and monitoring disease severity and complications[7,8].

An integrated approach that combines biochemical and cardiovascular assessments provides a more comprehensive understanding of CAD. Such evaluation not only aids in identifying individuals at high risk but also strengthens preventive and therapeutic decision-making. Therefore, the present retrospective study was undertaken to compare biochemical and cardiovascular parameters in CAD patients and healthy controls in Visakhapatnam, with the aim of identifying clinically relevant markers that may enhance early detection and guide patient management.

Research gap

Unlike earlier Indian studies that have typically focused on isolated markers such as lipid profile or glucose indices, the present work evaluates a comprehensive panel including haemoglobin, blood pressure, serum electrolytes, carbohydrate metabolism, lipid metabolism, liver function test, renal function test, echocardiography, treadmill testing and coronary angiography. By combining these domains in a retrospective case-control design, the study provides a region-specific perspective on clinically relevant markers of CAD. These findings highlight that only selected biochemical and cardiovascular parameters, rather than the entire panel, show significant association with CAD, thereby offering new insights for early risk identification, targeted prevention and therapeutic strategies in this population.

Rationale

Biochemical parameters reflect systemic metabolic alterations that are central to the pathophysiology of CAD. Assessing these parameters collectively, alongside cardiovascular findings, offers an opportunity to identify clinically significant markers that may aid in early diagnosis and management. By comparing CAD patients with healthy controls, this study aims to generate region-specific evidence from Visakhapatnam, thereby contributing to improved risk stratification, preventive strategies and therapeutic decision-making for CAD.

Objectives

1. To compare biochemical parameters (haemoglobin, blood pressure, serum electrolytes, carbohydrate metabolism, lipid metabolism, liver function test with proteins and renal function test) between CAD patients and controls.
2. To evaluate cardiovascular parameters (2D echocardiography and coronary angiography in patients; TMT in controls).

MATERIALS AND METHODS

Study design and population: A retrospective case-control study was conducted at Star pinnacle heart center hospital, Visakhapatnam Records of 200 CAD patients confirmed by coronary angiography and 200 healthy controls were reviewed. The study was approved by the Institutional Ethical committee, Andhra university, Visakhapatnam, India and informed consent was taken.

Sample collection: All blood samples were collected after 12 hours overnight fasting from intravenous blood was collected into 7ml in EDTA coated vacutainer tubes. Serum will be separated by centrifugation at 3000 rpm for 10 minutes and stored at -20°C.

Biochemical assays

Haemoglobin: Cyanmethemoglobin method.

Blood pressure: Measured using digital sphygmomanometer (Omron HEM-7203), following WHO protocol.

Serum electrolytes: Na^+, K^+, Cl^- measured by ion-selective electrode.

Carbohydrate metabolism: Fasting glucose by glucose oxidase-peroxidase method, PPG, HBA1c by High performance Liquid Chromatography.
Lipid profile: Total Cholesterol, triglycerides, HDL-C, LDL-C Enzymatic colorimetric method (CHOD/POD) calculated by Friedewald's formula.
Liver function tests (LFT): ALT, AST, Alkaline phosphate, total bilirubin, direct bilirubin measured by standard enzymatic methods); serum albumin and total protein measured by Biuret method.
Renal function tests (RFT): Blood Urea Nitrogen, serum creatinine, Uric acid- Photometry.
Cardiovascular assessments
CAD patients: 2D echocardiography (evaluating left ventricular ejection fraction (LVEF), wall motion abnormalities, chamber size) and coronary angiography by standard Judkins technique. Severity based on single, double or triple-vessel disease (stenosis ≥50% considered significant).
Controls: Treadmill test (TMT) Bruce protocol used ECG changes ≥1 mm ST depression considered positive.
Statistical analysis
Data were analyzed with SPSS version 20. Continuous variables were expressed as mean ± SD; t-test applied. Categorical variables were summarized as frequencies, percentages analyzed by chi-square test. Significance was set at $p < 0.05$.

RESULTS

Table - 1: Mean value of haemoglobin in males and females of CAD patients and Controls

Variable	CAD patients		t-test P value	Controls		t-test P value
	Males (N= 137) Mean±SD	Females (N= 63) Mean±SD		Males (N= 120) Mean±SD	Females (N= 80) Mean±SD	
Haemoglobin (gm/dL)	13±2.05	12.21±1.88	0.018	13.75±1.88	13.25±1.63	0.030

Table 1 represents, the mean haemoglobin concentration among CAD patients was 13 ± 2.05 g/dL in males and 12.21 ± 1.88 g/dL in females, while in controls it was 13.75 ± 1.88 g/dL in males and 13.25 ± 1.63 g/dL in females. The t-test P value was significant with both CAD patients (p = 0.018) and controls (p = 0.030).

Table - 2: Biochemical parameters of CAD patients and Controls

Biochemical parameters		CAD patients (N=200) Mean±SD	Controls (N=200) Mean±SD	t-test P value
Blood pressure	Systolic (mmHg)	132.58±9.39	123.65±6.81	<0.001
	Diastolic(mmHg)	86.24±4.77	81.49±3.46	<0.001
Serum Electrolytes	Sodium(mMol/L)	136.97±3.94	138.83±2.92	<0.001
	Potassium (mMol/L)	4.282±0.51	4.261±0.517	0.735
	Chloride (mMol/L)	100.42±5.47	99.81±4.31	0.213
Carbohydrate metabolism	Fasting blood glucose (mg/dL)	109.07±25.61	99.13±30.41	<0.001
	Post prandial glucose(mg/dL)	199.22±45.76	160.99±60.19	<0.001
	Glycosylated Hb (HbA1c) (%)	6.36±0.66	5.54±0.67	<0.001
Lipid metabolism	Total cholesterol (mg/dL)	223.27±10.75	175.94±43.12	<0.001
	Triglycerides (mg/dL)	195.89±34.87	157.09±25.84	<0.001

	HDL (mg/dL)	39.05±9.79	35.76±2.75	<0.001
	LDL (mg/dL)	139.41±12.31	99.37±47.82	<0.001
Liver function test with proteins	Alkaline phosphate(U/L)	77.87±20.69	65.64±9.52	<0.001
	Total bilirubin (mg/dL)	0.66±0.34	0.66±0.30	0.399
	Direct bilirubin (mg/dL)	0.22±0.17	0.3±0.14	<0.001
	AST (U/L)	32.98±11.37	36.65±11.50	0.001
	ALT (U/L)	24.77±10.88	38.89±6.30	<0.001
	Serum total proteins (gm/dL)	7.43±0.53	10.42±13.45	0.003
	Serum albumin (g/dL)	4.16±0.26	4.14±0.41	0.676
Renal function test	Blood urea nitrogen (mg/dL)	27.03±6.54	30.49±6.27	<0.001
	Serum creatinine (mg/dL)	0.79±0.22	0.91±0.19	<0.001
	Serum uric acid (mg/dL)	5.92±1.04	5.59±1.33	0.019

Table 2 represents, the mean biochemical parameters of CAD patients and controls according to blood pressure, serum electrolytes, carbohydrate metabolism, lipid metabolism, liver function test with proteins and renal function tests.

Blood Pressure

The mean systolic pressure among CAD patients was 132.58 ± 9.39 mmHg and in controls 123.65±6.81mmHg. The t-test P value was highly significant with systolic pressure. The mean diastolic pressure among CAD patients was 86.24 ± 4.77 mmHg and in controls 81.49 ± 3.46 mmHg. The t-test P value was highly significant with diastolic pressure.

Serum Electrolytes

The mean sodium level among CAD patients was 136.97 ± 3.94 mmol/L and in controls 138.83 ± 2.92 mmol/L. The t-test P value was highly significant with sodium. The mean potassium level among CAD patients was 4.282± 0.51 mmol/L and in controls 4.261 ± 0.517 mmol/L. The t-test P value was insignificant with potassium. The mean Chloride level among CAD patients was 100.42± 5.47 mmol/L and in controls 99.81 ± 4.31 mmol/L. The t-test P value was insignificant with chloride.

Carbohydrate Metabolism

The mean fasting blood glucose level among CAD patients was 109.07 ± 25.61 mg/dL and in controls 99.13 ± 30.41 mg/dL. The t-test P value was highly significant with fasting blood glucose. The mean postprandial blood sugar level among CAD patients was 199.22 ± 45.76 mg/dL and in controls 160.99 ±
60.19 mg/dL. The t-test P value was highly significant with post prandial blood sugar. The mean HbA1c level among CAD patients was 6.36 ± 0.66% and in controls 5.54 ± 0.67%. The t-test P value was highly significant with HbA1c.

Lipid metabolism

The mean total cholesterol level among CAD patients was 223.27 ± 10.75 mg/dL and in controls 175.94 ±
43.12 mg/dL. The t-test P value was highly significant with total cholesterol. The mean triglycerides level among CAD patients was 195.89 ± 34.87 mg/dL and in controls 157.09 ± 25.84 mg/dL. The t-test P value was highly significant with triglycerides. The mean HDL level among CAD patients was 39.05 ± 9.79 mg/dL and in controls 35.76 ± 2.75 mg/dL. The t-test P value was highly significant with HDL. The mean LDL level among CAD patients was 139.41 ± 12.31 mg/dL and in controls 99.37 ± 47.82 mg/dL. The t-test P value was highly significant with LDL.

Liver Function Test with Proteins

The mean alkaline phosphate (ALP) level among CAD patients was 77.87 ± 20.69 U/L and in controls 65.64 ± 9.52 U/L. The t-test P value was highly significant with ALP. The mean total bilirubin level among CAD patients was 0.66 ± 0.34 mg/dL and in controls 0.66 ± 0.30 mg/dL. The t-test P value was insignificant with total bilirubin. The mean direct bilirubin level among CAD patients was 0.22 ± 0.17

mg/dL and in controls 0.3 ± 0.14 mg/dL. The t-test P value was highly significant with direct bilirubin. The mean Aspartate Aminotransferase (AST) level among CAD patients was 32.98 ± 11.37 U/L and in controls
36.65 ± 11.50 U/L. The t-test P value was significant with AST. The mean Alanine Aminotransferase (ALT) level among CAD patients was 24.77 ± 10.88 U/L and in controls 38.89 ± 6.30 U/L. The t-test P value was highly significant with ALT. The mean serum total proteins level among CAD patients was 7.43 ± 0.53 g/dL and in controls 10.42 ± 13.45 g/dL. The t-test P value was significant with serum total proteins. The mean serum albumin level among CAD patients was 4.16 ± 0.26 g/dL and in controls 4.14 ± 0.41 g/dL. The t-test P value was insignificant with serum albumin.

Renal Function Tests

The mean blood urea nitrogen (BUN) level among CAD patients was 27.03 ± 6.54 mg/dL and in controls 30.49 ± 6.27 mg/dL. The t-test P value was highly significant with BUN. The mean serum creatinine among CAD patients was 0.79 ± 0.22 mg/dL and in controls 0.91 ± 0.19 mg/dL. The t-test P value was highly significant with serum creatinine. The mean serum uric acid among CAD patients was 5.92 ± 1.04 mg/dL and in controls 5.59 ± 1.33 mg/dL. The t-test P value was significant with serum uric acid.

Table - 3: Distribution of CAD patients according to 2D ECHO

2D ECHO	Male N= 137 (%)	Female N= 63(%)	Total N= 200(%)	χ^2	P-Value
Mild LVD	92 (67.15)	38 (60.31)	130 (65)	0.8946	0.3442
Moderate LVD	43 (31.38)	24 (38.09)	67 (33.5)		
Sever LVD	2 (1.45)	1 (1.58)	3 (1.5)		

Table 3 represents, the chi-square p value of 2D echocardiographic assessment of CAD patients was 0.8946 and demonstrated that the majority exhibited mild left ventricular dysfunction (65%), followed by moderate dysfunction (33.5%), whereas only 1.5% presented with severe dysfunction. The insignificant p value was observed for 2D ECHO.

Table - 4: Distribution of CAD patients according to Coronary Angiogram

Coronary Angiogram	Male N= 137 (%)	Female N= 63 (%)	Total N= 200(%)	χ^2	P-Value
SVD	55 (40.14)	28 (44.44)	83 (41.5)	0.6307	0.4271
DVD	47 (34.30)	22 (34.92)	69 (34.5)		
TVD	35 (25.54)	13 (20.63)	48(24)		

Table 4 represents, the chi-square p value of coronary angiogram assessment of CAD patients was 0.6307 and revealed that single vessel disease was the most common pattern (41.5%), followed by double vessel disease (34.5%) and triple vessel disease (24%). The insignificant p value was observed for coronary angiogram.

Table - 5: Distribution of Controls according to TMT

TMT	Male N= 120(%)	Female N= 80 (%)	Total N=200(%)	χ^2	P-Value
Positive	10 (8.33)	14 (17.5)	24 (12)	3.8194	0.0507
Negative	110 (91.6)	66 (82.5)	176 (88)		

Table 5 represents, the chi-square p value of treadmill test of controls was 3.8194. TMT test exhibits 12% positive and 88% negative results. The insignificant p value was observed for TMT.

DISCUSSION

Clinically, our findings suggest that selected biochemical parameters-particularly haemoglobin, glucose metabolism and lipid profile can serve as practical markers for early detection and risk stratification of CAD. These markers may help clinicians identify high-risk individuals, guide preventive strategies and optimize therapeutic interventions, especially in the Visakhapatnam population.

The present study evaluated the biochemical and cardiovascular parameters of coronary artery disease patients compared with healthy controls in Visakhapatnam. Our findings demonstrate that significant p value was observed for haemoglobin level. While highly significant p value was observed for blood pressure (systolic, diastolic), carbohydrate metabolism (fasting blood glucose, post prandial glucose, HbA1c) and lipid metabolism (total cholesterol, triglycerides, LDL, HDL). In serum electrolytes highly significant p value was observed for sodium, whereas for potassium and chloride the p value was insignificant. In liver function test the highly significant p value was observed for alkaline phosphate, direct bilirubin and ALT. Significant p value was observed for AST and serum total proteins whereas for total bilirubin, serum albumin the p value was insignificant. In renal function test the highly significant p value was observed for blood urea nitrogen, serum creatinine whereas for serum uric acid the p value was insignificant. Cardiovascular assessments including 2D echocardiography, treadmill testing and coronary angiography exhibits insignificant p value.

Haemoglobin is an important determinant of oxygen-carrying capacity and tissue perfusion. Both low and high levels have been linked to cardiovascular morbidity and mortality. Low haemoglobin (anemia) contributes to myocardial ischemia by reducing oxygen delivery, while high haemoglobin (polycythemia) may increase blood viscosity and thrombosis risk. Thus, maintaining optimal haemoglobin balance is critical in cardiovascular health.

Our findings are in agreement with (Shah et al., 2011)[10], who reported that lower haemoglobin levels were associated with worse prognosis in patients with stable coronary heart disease, establishing clinically relevant thresholds for haemoglobin in CAD. Similarly, (Kengne et al., 2012)[11] showed that anemia significantly increased cardiovascular mortality, particularly among individuals with diabetes, which is highly relevant to our population where CAD patients also demonstrated higher glucose and HbA1c levels. More recently, (Steinke et al., 2024)[12] found that anemia independently predicted rehospitalization and adverse outcomes in patients undergoing coronary angiography, reinforcing the prognostic role of haemoglobin in CAD management.

In the present study, both systolic and diastolic blood pressures were significantly elevated in CAD patients compared to controls, Numerous studies recognize hypertension as a critical, independent risk factor for CAD, with systolic pressure particularly predictive of coronary events. consistent with their established role as major independent cardiovascular risk factors. Elevated systolic blood pressure, in particular, has been shown to strongly predict coronary events, while excessively low diastolic pressure may increase cardiac risk due to impaired coronary perfusion-producing a J-shaped risk curve. These findings align with longitudinal cohort analyses and international guidelines emphasizing tight blood pressure control to mitigate CAD risk[13,14,15].

In the present study for serum electrolytes highly significant p value was observed for sodium, whereas for potassium and chloride the p value was insignificant. However, the role of electrolyte homeostasis in cardiovascular health has been well documented and disturbances may contribute to both disease development and prognosis. Recent large cohorts show that even mild hyponatremia or disturbances in serum potassium or chloride impact cardiovascular risk, mortality and arrhythmia propensity (especially in CAD)[16]. However, subtle electrolyte shifts may be influenced by medications (e.g., diuretics), comorbid conditions and do not alone cause CAD but add to risk assessment[17].

In the present study, highly significant p value was observed for carbohydrate metabolism (fasting blood glucose, post prandial glucose and HbA1c), underscoring the strong link between impaired carbohydrate metabolism and coronary risk. Poor glycemic control is tightly linked with advanced atherosclerosis, enhanced plaque instability and worse outcomes. Meta-analyses show postprandial glucose is a strong predictor of overall glycemic control (HbA1c correlates more with postprandial than fasting glucose for moderate elevations) and that elevated HbA1c, even at pre-diabetic levels, is associated with increased CAD risk[18,19,20]. Our results, therefore, reinforce the clinical importance of integrating FBG, PPG and HbA1c measurements into cardiovascular risk assessment, even in populations without overt diabetes. Early identification and treatment of dysglycemia may help to mitigate the progression of coronary atherosclerosis and reduce CAD burden. Elevated postprandial glucose, in particular, has emerged as a

key contributor to glycation end-products and endothelial dysfunction leading to CAD. HbA1c remains a gold-standard marker for chronic glucose control and cardiovascular risk stratification.

In the present study, for lipid profile analysis highly significant p value was observed for total cholesterol, triglycerides, low-density lipoprotein cholesterol and high-density lipoprotein cholesterol. These findings align with the established role of dyslipidemia as a major risk factor for coronary atherosclerosis and adverse cardiovascular events[21]. Multiple studies-recent and global-continue to confirm that higher LDL and non-HDL cholesterol are independent predictors of CAD, while lower HDL is inversely related to cardiovascular risk[22]. Despite advances, suboptimal lipid control persists in high-risk populations, underscoring aggressive lipid lowering in secondary prevention[23]. Despite advances in lipid-lowering therapies, suboptimal control remains an issue, highlighting the continuous need for aggressive lipid management in CAD patients. In contrast, HDL-C has been considered cardioprotective due to its role in reverse cholesterol transport, anti-inflammatory, antioxidant and endothelial-protective functions. Prospective cohort studies, such as the INTERHEART study, demonstrated that low HDL-C is one of the strongest predictors of myocardial infarction globally[24]. In our study, the significant reduction in HDL-C among CAD patients further supports its role as an independent protective factor.

Overall, our findings of elevated total cholesterol, triglycerides, LDL-C, coupled with reduced HDL-C in CAD patients, are consistent with the global literature on dyslipidemia and cardiovascular disease. Mechanistically, these lipid alterations promote endothelial dysfunction, oxidative stress and plaque instability, thereby contributing to the initiation and progression of coronary artery disease.

In the present study, the highly significant p value was observed for alkaline phosphate, direct bilirubin, ALT and significant p value was observed for AST and serum total proteins whereas for total bilirubin and serum albumin the p value was insignificant. These findings highlight the complex interplay between hepatic function and cardiovascular disease. Changes in liver enzyme levels (mildly increased AST, ALT or ALP) are often seen in CAD and may reflect hepatic congestion, metabolic syndrome or concurrent NAFLD (Non-alcoholic Fatty Liver Disease) rather than primary liver disease. Some research suggests that albumin and aminotransferases, even within normal ranges, may be associated with atherosclerosis burden, but clinical significance is nuanced. Variability in findings may relate to patient selection or comorbidities[25,26].

In the present study, the highly significant p value was observed for blood urea, serum creatinine whereas for serum uric acid the p value was insignificant, indicating a strong link between impaired renal function, metabolic derangements and cardiovascular pathology. Renal function parameters including BUN, creatinine and uric acid were higher in CAD patients, corroborating the recognized bidirectional relationship between renal impairment and cardiovascular disease. Even mild elevations in these markers predict adverse outcomes, emphasizing their inclusion in risk stratification strategies[27]. Additionally, elevated uric acid has emerged as an independent cardiovascular risk factor, linked to endothelial dysfunction and inflammation[28,29]. Taken together, our findings reinforce that renal function markers-blood urea, serum creatinine and uric acid should not only be considered as indicators of renal status but also as independent cardiovascular risk markers. Their incorporation into CAD risk stratification may improve early detection of high-risk patients and guide more intensive management.

In the present study, the p value was insignificant with 2D echocardiographic. These findings suggest that although LV systolic dysfunction is a common consequence of CAD, the severity distribution may vary depending on disease progression, comorbidities and treatment status. 2D ECHO remains a cornerstone imaging modality for assessing left ventricular function, enabling non-invasive evaluation of ejection fraction and wall motion abnormalities indicative of ischemic cardiomyopathy. While advanced imaging techniques like gated SPECT and PET may provide superior accuracy in some settings, 2D ECHO is widely accessible and cost-effective for initial assessment and longitudinal monitoring. The presence of LVD on echocardiography correlates with symptomatic heart failure, poor exercise tolerance, and increased risk of adverse events, emphasizing its role in guiding treatment decisions, including medical therapy and revascularization strategies[30-34]. Gender comparisons in echocardiographic parameters often show no significant differences in left ventricular ejection fraction or volumes across CAD patients, aligning with meta-analyses that report similar cardiac remodeling patterns and functional metrics between males and females with ischemic heart disease. Understanding the extent of LVD via echocardiographic parameters helps stratify patients risk and tailor interventions for improved prognosis[35].

Taken together, it was observed the role of 2D echocardiography as a cost-effective and clinically relevant modality to assess cardiac dysfunction in CAD. Early identification of LV dysfunction through routine echocardiographic screening may improve risk stratification, therapeutic decision- making and long-term

prognosis.

In the present study, the insignificant p value was observed for coronary angiography, these findings align with previous epidemiological studies, which report SVD as the most common presentation in stable CAD populations. This distribution is consistent across males and females without significant gender differences. Single vessel disease is most commonly observed in CAD patients, particularly younger populations, and is generally associated with a more favorable prognosis compared to multi- vessel involvement. Studies have shown that SVD, particularly when localized to the left anterior descending artery, tends to present with less extensive ischemia and better survival rates[36].Double and triple vessel disease represent more advanced atherosclerotic burden, with increasing risk of adverse cardiovascular outcomes, including myocardial infarction and heart failure. The prognosis worsens proportionally with the number of coronary arteries involved. Importantly, patients with TVD have a significantly higher mortality rate and often require more complex interventions such as coronary artery bypass grafting (CABG). Recent large cohort studies report that TVD patients benefit significantly from surgical revascularization strategies, which improve survival and reduce repeat ischemic events compared to medical therapy alone[37].Gender-based analysis of angiographic CAD patterns reveals mixed results. Some studies indicate that males more frequently have extensive disease and calcification, whereas females tend to show smaller coronary artery diameters but similar disease severity. However, no significant gender differences in the distribution of SVD, DVD, and TVD are consistently found. These nuances highlight the importance of individualized assessment and management considering both anatomical extent and patient-specific factors[38].Overall, coronary angiogram remains the gold standard to define anatomical CAD burden, crucial for prognostication and tailoring therapeutic approaches.

The treadmill test is a widely used non-invasive diagnostic and prognostic tool for detecting coronary artery disease, especially effective among asymptomatic individuals and controls. In the present study, among 200 control participants, (12%) demonstrated a positive treadmill test, with a statistically borderline higher positivity in females (17.5%) compared to males (8.33%). This gender difference in TMT positivity aligns with existing literature suggesting women often have higher false-positive rates due to factors like hormonal influences, smaller heart size and autonomic differences[39]. The positive treadmill test in controls is clinically significant as it may indicate the presence of silent myocardial ischemia or early-stage CAD, warranting further evaluation. Studies report that treadmill stress testing, by assessing heart rate response, exercise capacity, and ECG changes (e.g., ST-segment deviation), provides valuable screening information not only for diagnosing CAD but also for prognosticating future cardiac events. Sensitivity and specificity for TMT vary but generally fall around (70-80%), with higher false positives among women and individuals with non-cardiac causes for test abnormalities[40]. Moreover, treadmill test results are influenced by traditional risk factors such as age, hypertension, diabetes mellitus and smoking, which independently increase CAD risk. The test also helps guide lifestyle interventions and risk factor modifications in controls to reduce CAD progression. Gender-specific considerations in treadmill testing, including interpretation of exercise capacity and heart rate recovery, further enhance its clinical utility for personalized cardiovascular risk stratification[41,42]. Overall, our results highlight that even asymptomatic controls may have latent ischemic changes detectable by TMT and such individuals should be considered for preventive strategies to reduce future cardiovascular events.

Limitations of the Study

The study was based on a limited sample size, which may not fully represent the general population. This could restrict the external validity and generalizability of the findings. Since the study design was cross-sectional, causal relationships between biochemical parameters and coronary artery disease severity cannot be firmly established. Single-time measurement of biochemical markers (e.g., fasting blood glucose, HbA1c, lipid profile, renal and liver function tests) may not reflect long-term metabolic status. Diagnostic procedures such as 2D echocardiography, treadmill test and coronary angiography were used, but inter-observer variability and technical limitations may have affected accuracy.

Strengths of the Study

A key strength of this study is its comprehensive assessment, incorporating both biochemical markers (haemoglobin, serum electrolytes, lipid profile, carbohydrate metabolism indices, liver and renal function tests) and cardiovascular evaluations (2D echocardiography, treadmill testing and coronary angiography). This integrated approach provides a holistic understanding of coronary artery disease. The use of angiography as the diagnostic gold standard ensured accurate case classification, while the inclusion of age-matched controls allowed meaningful comparison. Furthermore, this study contributes population-

specific data from Visakhapatnam, where limited evidence is available.

Future Implications

The present study highlights the relevance of combining biochemical markers with cardiovascular diagnostic tools in the evaluation of coronary artery disease. Biochemical parameters such as haemoglobin, blood pressure, glucose metabolism, lipid parameters, renal function test, liver function tests and should be considered alongside cardiovascular assessments including 2D echocardiography, treadmill testing and coronary angiography for comprehensive disease assessment. Incorporating these measures into routine clinical practice may improve early diagnosis, risk stratification and therapeutic decision-making in CAD patients. Future research with larger cohorts and longitudinal follow-up is required to strengthen the clinical applicability of these findings and to establish standardized protocols for integrating biochemical and cardiovascular evaluations.

CONCLUSION

This study provides evidence that haemoglobin levels was significant. Strong association was for observed for blood pressure, carbohydrate metabolism and lipid metabolism, emphasizing their role in disease status. In contrast, serum electrolytes, liver function tests, renal function tests and cardiovascular diagnostic assessments, including 2D echocardiography, coronary angiography and treadmill testing, did not show strong association. Collectively, these findings indicate that selected biochemical and cardiovascular parameters may serve as valuable markers for identifying individuals at high risk of CAD and may support the development of preventive and therapeutic strategies.

Overall, this study highlights the importance of specific biochemical markers in CAD pathophysiology and underscores their potential utility in clinical practice. Future prospective studies with larger cohorts are warranted to validate these findings and explore their predictive value in CAD progression and outcomes.

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