ORIGINAL RESEARCH CVD & BIOCHEMISTRY

# Comparative efficacy of serum NT-proBNP versus AST for detecting cardiac dysfunction in diabetic patients with heart disease

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## ABSTRACT

**Background & objective:** Type 2 diabetes mellitus (T2DM) significantly increases the risk of cardiovascular diseases (CVD). The early detection of subclinical cardiac dysfunction in this population is critical for improving clinical outcomes, necessitating the identification of sensitive and specific biomarkers. We compared the diagnostic utility of cardiac biomarkers N-terminal pro-brain natriuretic peptide (NT-proBNP) and aspartate aminotransferase (AST), and lipid profiles in diabetic patients with cardiovascular disease (CVD) and healthy controls.

**Methodology:** A case-control study was conducted at the Al-Fayhaa Teaching Hospital in Basrah, Iraq, between November 2024 and April 2025. We enrolled 140 participants; 70 diabetic patients with known CVD and 70 healthy controls, aged 41–76 years. Serum levels of NT-proBNP, AST, and lipid parameters (total cholesterol, triglycerides, HDL, LDL, and VLDL) were measured using a Cobas e411 analyzer.

**Results:** NT-proBNP levels were significantly elevated in patients compared to controls (0.308 ± 0.20 vs. 0.211 ± 0.14; P < 0.001); whereas AST levels did not differ significantly (22.13 ± 9.59 vs. 24.31 ± 7.10; P = 0.13). Patients also exhibited more atherogenic lipid profile, with higher total cholesterol, triglycerides, and VLDL, and lower HDL levels (all P < 0.001).

**Conclusion:** NT-proBNP is more sensitive than AST to the detection of chronic myocardial stress and subclinical cardiac dysfunction in patients with diabetes and CVD. Inclusion of NT-proBNP in routine diabetic care with lipid management could potentially improve early risk stratification and preventive actions in reducing cardiovascular disease burden.

**Abbreviations:** AST: aspartate aminotransferase, CVD: cardiovascular disease, NT-proBNP: N-terminal pro-brain natriuretic peptide, T2DM: Type 2 diabetes mellitus

**Keywords:** Type 2 diabetes mellitus; NT-proBNP; Diabetic cardiomyopathy; Aspartate aminotransferase.

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## 1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic endocrine and metabolic disorder that affects nearly 500 million individuals worldwide, with projections indicating continued exponential growth.[1] The complex interplay between diabetes and CVD results in a pathophysiological environment characterized by premature atherosclerosis, endothelial dysfunction, and incremental cardiac structural and functional changes. This bidirectional relationship forms a vicious circle that diabetes leads to cardiovascular diseases and vice versa the heart impairment exacerbates glucose homeostasis.[2,3] The pathogenesis of diabetic heart complications is the result of several interrelated factors. Persistent hyperglycemia leads to the generation of AGEs that contribute to the development of vascular stiffness and endothelial dysfunction.[4] These molecular alterations, along with oxidative stress, inflammation and metabolism disorders, participate in resulting diabetic on its own, as a separate clinical entity with certain structure and function cardiac disorders, unrelated to coronary artery disease.[5] The early detection of cardiac dysfunction in patients with diabetes presents significant clinical challenges. Traditional diagnostic approaches often fail to identify subclinical cardiac abnormalities, leading to delayed intervention and poor outcomes.[6] As a result, there is an increasing demand for reliable, easy-to-use, and affordable biomarkers that can detect cardiac insufficiency in its earliest stage, prior to irreversible myocardial injury.[7,8]

N-terminal pro-brain natriuretic peptide (NT-proBNP) is considered as the biomarker of choice for heart failure diagnosis and cardiovascular risk assessment. This biologically inactive fragment, from proBNP processing, is released in the presence of ventricular wall stress, volume overload and myocardial failure.[9] In the diabetic population, NT-proBNP is of special importance in that it does not only reflect manifest heart failure, but also reflects subclinical heart diseases in addiction to established symptomatic heart disease.[10,11] The value of NT-proBNP in patients with diabetes is not limited to its diagnostic role for heart failure. Data from recent studies suggest that diabetic patients may have NT-proBNP levels that are elevated in the absence of symptomatic HF, which is consistent with myocardial strain and diastolic dysfunction.[12] This observation indicates that diabetes-related cardiac alterations take place earlier than previously appreciated, highlighting the potential role of NT-proBNP as a screen for subclinical myocardial dysfunction.[9]

In addition to diagnosing BNP, NT-proBNP can be used to predict prognosis of DM patients. Several studies have shown that an increase in NT-proBNP is more effective than other traditional markers (HbA1c and albuminuria) to predict cardiovascular mortality.[13,14] The prognostic utility of biomarkers remains for different diabetic subgroups, including those with subclinical cardiac function.[15] Recent recommendations have acknowledged indeed the relevance of NT-proBNP in diabetics, as reflected in the 2023 consensus of the Heart Failure Association, and recommended the evaluation of natriuretic peptides in diabetic patients to uncover "heart stress", a newly condition depicting asymptomatic individuals or those with risk factors and pathologic natriuretic peptides levels.[16] This concept acknowledges the unique vulnerability of patients with diabetes to cardiac dysfunction and emphasizes the role of biomarker-guided screening in early detection and intervention.[17] This study aimed to assess and compare the levels of cardiac biomarkers (NT-proBNP and AST) and lipid profiles between diabetic patients with heart disease and healthy controls to determine their clinical relevance.

## 2. METHODOLOGY

This case-control study was conducted at the Al-Fayhaa Teaching Hospital in Basrah, Iraq, between November 2024 and April 2025. The study protocol was reviewed and approved by the Institutional Review Board (IRB) of [The Southern Technical University and the Basra College of Health and Medical Techniques cooperated to conduct this study. It was approved by the research committee (number 506) on September 9, 2024, based on the Helsinki Declaration.]). Written informed consent was obtained from all participants prior to their enrollment in the study.

### 2.1. Study Participants

A total of 140 participants were recruited and divided into two groups: The Patient Group (cases): 70 adult patients (35 males and 35 females) with a confirmed diagnosis of T2DM according to the American Diabetes Association (ADA) criteria and comorbid heart disease (including heart failure, ischemic heart disease, or hypertensive heart disease). The control Group consisted of 70 age- and sex-matched healthy individuals (34 males and 36 females) with no history of diabetes, cardiovascular disease, or other chronic illnesses. Inclusion Criteria for Patients: Diagnosis of T2DM, age between 40-80 years, and documented heart disease (e.g., based on echocardiographic findings, clinical history, or previous hospitalization). Exclusion criteria: Patients with acute myocardial infarction within the past three months, severe hepatic or renal impairment, active infection, malignancy, or medication known to significantly affect cardiac biomarkers (e.g., recent nephrotoxic drugs) were excluded from the study.

### 2.2. Sample Collection / Processing

After a 12-hour overnight fast, approximately 5 mL of venous blood was drawn from each participant using a sterile technique. Blood samples were collected in gel-clot activator vacuum tubes (SST™). The samples were allowed to clot at room temperature for 30 min and subsequently centrifuged at 4000 revolutions per minute (rpm) for 10 min to separate the serum. The aliquoted serum samples were stored at -20°C until batch analysis to avoid inter-assay variation.

## 2.3. Biochemical Analysis

All biochemical parameters were measured using a fully automated electrochemiluminescence immunoassay (ECLIA) analyzer (Cobas e411 (Roche Diagnostics, Germany) following the manufacturer's protocols. NT-proBNP was quantified using ECLIA. The measurement range of the assay was 5–35,000 pg/mL. AST: Measured using the International Federation of Clinical Chemistry (IFCC) method without pyridoxal phosphate activation. Lipid Profile: The following parameters were analyzed using an enzymatic colorimetric method.

**Table 1: Baseline Sociodemographic Characteristics of the Study Participants**

| Characteristic | | Patients group (n = 70) | Control group (n = 70) | P-value |
|---|---|---|---|---|
| **Age (year)** | | 56.66 ± 7.90 | 54.61 ± 7.54 | 0.12 |
| **Gender** | **Male** | 35 (50.0) | 34 (48.6) | 0.96 |
| | **Female** | 35 (50.0) | 36 (51.4) | |
| **Residence** | **Urban** | 37 (52.9) | 35 (50.0) | 0.73 |
| | **Rural** | 33 (47.1) | 35 (50.0) | |

*Data presented as mean ± SD or n (%); P < 0.05 is significant, *t-test, ** chi-square test.*

## 2.4. Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro-Wilk test and are presented as the mean ± standard deviation (SD). Categorical variables were expressed as numbers and percentages (%). An independent samples t-test was used to compare the means of the continuous variables between the two groups. For categorical variables, the chi-squared ($\chi^2$) test was used. Statistical significance was set at a two-tailed p-value ≤ 0.05.

# 3. RESULTS

Table 1 summarizes the baseline sociodemographic characteristics of the 140 participants, comprising 70 patients with diabetes and heart disease and 70 healthy controls. The two groups were well-matched, showing no statistically significant differences in age (Patients: 56.66 ± 7.90 years vs. Controls: 54.61 ± 7.54 years; P = 0.12), sex distribution (50.0% male in both groups; P = 0.96), or residential status (Urban: 52.9% patients vs. 50.0% controls; P = 0.73). This demographic equivalence suggests that any observed differences in biochemical parameters are likely attributable to the disease state rather than baseline variables.

As presented in Table 2, the serum NT-proBNP concentration was significantly higher in the patient group than in the healthy controls (0.308 ± 0.20 vs. 0.211 ± 0.14, P < 0.001). This finding indicates a state of chronic myocardial stress and subclinical cardiac dysfunction in patients with diabetes and heart disease. In stark contrast, the levels of AST did not differ significantly between the groups (22.13 ± 9.59 IU/L vs. 24.31 ± 7.10 IU/L; P = 0.13), highlighting its lack of sensitivity for detecting non-acute cardiac dysfunction in this population.

The analysis of cardiac biomarkers according to sex in the diabetic patient cohort is shown in Table 3. No statistically significant differences were observed in NT-proBNP levels between males and females (0.32 ± 0.21 vs. 0.29 ± 0.18; P = 0.60). Similarly, AST levels showed no significant sex-based variation (24.19 ± 10.44 IU/L vs. 20.01 ± 8.27 IU/L; P = 0.07), although a trend toward higher values in males was noted.

Table 4 details the comprehensive lipid profile analysis, revealing a profoundly atherogenic dyslipidemia in the patient group. Diabetic patients with heart disease exhibited significantly higher levels of total cholesterol (193.93 ± 57.48 mg/dL vs. 163.40 ± 34.02 mg/dL; P < 0.001), triglycerides (224.94 ± 102.84 mg/dL vs. 112.50 ± 35.72 mg/dL; P < 0.001), and VLDL (41.73 ± 19.69 mg/dL vs. 26.69 ± 14.58 mg/dL; P < 0.001) compared to controls. High-density lipoprotein (HDL) cholesterol, the protective lipid fraction, was significantly lower in patients (33.95 ± 10.03 mg/dL vs. 40.80 ± 8.28 mg/dL; P < 0.001). LDL cholesterol levels

**Table 3: Cardiac Biomarker Levels Stratified by Sex within the Diabetic Patient Group**

| Parameters | Male group (n = 35) | Female group (n = 35) | P- value |
|---|---|---|---|
| **NT-proBNP** (ng/mL) | 0.32 ± 0.21 | 0.29 ± 0.18 | 0.60 |
| **AST** (IU/L) | 24.19 ± 10.44 | 20.01 ± 8.27 | 0.07 |

*Data presented as mean ± SD; P < 0.05 is significant, *t-test, ** chi-square test.*

**Table 3: Cardiac biomarker levels stratified by gender within the Diabetic Patient Group**

| Parameters | Male group (n = 35) | Female group (n = 35) | P- value |
|---|---|---|---|
| **NT-proBNP (**ng/mL**)** | 0.32 ± 0.21 | 0.29 ± 0.18 | 0.60 NS |
| **AST (**IU/L**)** | 24.19 ± 10.44 | 20.01 ± 8.27 | 0.07 NS |

*Data presented as mean ± SD; P < 0.05 is significant,*

**Table 4: Comparative analysis of lipid profile parameters between the study groups**

| Parameters | Patient group (n = 70) | Control group (n = 70) | P-value |
|---|---|---|---|
| **T.C (mg/dl)** | 193.93 ± 57.48 | 163.40 ± 34.02 | < 0.001 |
| **TG (mg/dl)** | 224.94 ± 102.84 | 112.50 ± 35.72 | < 0.001 |
| **HDL (mg/dl)** | 33.95 ± 10.03 | 40.80 ± 8.28 | < 0.001 |
| **LDL (mg/dl)** | 116.52 ± 46.07 | 120.99 ± 39.55 | 0.54 |
| **VLDL (mg/dl)** | 41.73 ± 19.69 | 26.69 ± 14.58 | < 0.001 |

*Data presented as mean ± SD; P < 0.05 is significant,*

were comparable between the two groups (116.52 ± 46.07 mg/dL vs. 120.99 ± 39.55 mg/dL; P = 0.54).

# 4. DISCUSSION

This study provides compelling evidence for the superior diagnostic utility of N-terminal pro-B-type natriuretic peptide over AST in identifying subclinical cardiac dysfunction in diabetic patients with heart disease. These findings reaffirm the characteristic atherogenic lipid profile associated with diabetic cardiovascular complications. The observed significant elevation of NT-proBNP in diabetic patients with heart disease compared to healthy controls is consistent with the established pathophysiology of diabetic cardiomyopathy. NT-proBNP is released from ventricular cardiomyocytes in response to myocardial wall stretch, volume overload, and pressure and serves as a sensitive biomarker of myocardial stress. Its elevation in this cohort reflects the chronic hemodynamic burden inherent to diabetic cardiovascular disease, even in the absence of overt myocardial infarction.[18,19] Furthermore, insulin resistance and hyperglycemia contribute to myocardial stiffness and diastolic dysfunction, which subsequently increases cardiac wall tension and stimulates pro-BNP secretion.[20] This mechanistic link is supported by sub-analyses demonstrating that patients with concomitant heart failure and diabetes exhibit significantly higher pro-BNP levels than their non-diabetic counterparts independent of ejection fraction.[21]

Clinically, NT-proBNP demonstrates robust diagnostic performance for cardiac dysfunction in diabetic patients. Comprehensive analyses have reported a sensitivity of 73–84% and a specificity of 75–82% for this purpose. Notably, a concentration threshold of > 490 fmol/mL yielded 84% sensitivity and 75% specificity for detecting underlying ischemic heart disease in patients.[7,9] The clinical relevance of these findings is underscored by the recent consensus guidelines. The Heart Failure Association of the European Society of Cardiology introduced the concept of "heart stress," characterizing asymptomatic individuals with risk factors and elevated NT-proBNP levels. Large-scale studies have indicated that approximately one-third of adults with diabetes have subclinical cardiovascular disease, as detected by cardiac biomarkers. Within this context, NT-proBNP has emerged as a powerful independent predictor of cardiovascular mortality, reflecting the interplay between insulin resistance, hyperglycemia-induced myocardial dysfunction, and subsequent ventricular stress.[9,22]

In contrast to NT-proBNP, the absence of significant differences in AST levels between patients with diabetes and controls highlights the limited sensitivity of this biomarker for detecting subclinical cardiac dysfunction in diabetes. AST, which is present in the cardiac muscle, is a non-specific transaminase enzyme predominantly found in the liver and skeletal muscle tissues. This lack of cardiac specificity renders AST less suitable for detecting the chronic low-grade myocardial stress characteristic of diabetic cardiomyopathy, as opposed to acute myocardial injury scenarios where more substantial cardiac enzyme release occurs.[23] The observed pattern supports the understanding that patients with diabetes and coronary heart disease are characterized by chronic myocardial stress rather than overt myocardial infarction, necessitating the use of more sensitive cardiac biomarkers for early risk stratification.[24] This finding emphasizes the importance of biomarker selection in diabetic populations, in which subclinical cardiac abnormalities may precede symptomatic disease by year.[25]

 

The lipid profile abnormalities observed in the present study exemplify the classic triad of diabetic dyslipidemia, which is characterized by elevated total cholesterol, hypertriglyceridemia, reduced HDL cholesterol, and elevated VLDL. This atherogenic pattern represents a fundamental component of diabetic cardiovascular risk and reflects the complex metabolic derangements associated with insulin resistance.[26–28] The pathophysiological basis for these lipid abnormalities lies in the insulin-resistant state, characteristic of type 2 diabetes.[29,30] Insulin resistance at the adipocyte level results in increased release of free fatty acids into the circulation, stimulating hepatic VLDL assembly and secretion, thereby contributing to hypertriglyceridemia.[27] The observed elevation in VLDL particles facilitates the exchange of cholesteryl esters from HDL and LDL for VLDL triglycerides via cholesteryl ester transfer protein, ultimately leading to the formation of small dense LDL particles and accelerated HDL clearance.[31] The reduced HDL cholesterol levels observed in the study population are particularly concerning, as HDL particles provide crucial anti-atherogenic, anti-inflammatory, and antioxidant effects through reverse cholesterol transport and protection of endothelial function.[32] In patients with diabetes, HDL particles undergo qualitative impairment, becoming glycated and oxidized, which compromises their protective cardiovascular functions. This dysfunction is mechanistically mediated through insulin resistance, which increases hepatic lipase activity and HDL catabolism, while simultaneously depressing apolipoprotein A-I production.[33,34]

The concurrent elevation of NT-proBNP and atherogenic dyslipidemia in diabetic patients with heart disease creates a compounding cardiovascular risk profile that extends beyond traditional risk factors. Studies have consistently demonstrated that the triglyceride-to-HDL cholesterol ratio serves as a robust cardiovascular risk predictor in patients with type 2 diabetes and is often superior to conventional lipid parameters.[35,36] The metabolic clustering of high triglycerides, low HDL cholesterol, and elevated total cholesterol observed in this study represents the broader phenotype of diabetic dyslipidemia, which serves not only as a marker of cardiovascular risk but also as a therapeutic target.[37] The integration of NT-proBNP assessment into routine diabetic care aligns with recent American Diabetes Association guidelines, which recommend biomarker testing to identify patients at the highest risk of progressing to symptomatic heart failure. The biomarker-guided approach facilitates the early identification of subclinical cardiac dysfunction, enabling timely implementation of evidence-based cardiovascular protective therapies and lifestyle interventions before irreversible myocardial damage occurs.[38,39]

# 5. LIMITATIONS

While this study provides valuable insights into the utility of cardiac biomarkers in patients with diabetes, several limitations warrant consideration. This cross-sectional design provides only a snapshot of biomarker levels and lipid profiles, limiting the assessment of temporal relationships and disease progression. Future longitudinal studies incorporating serial NT-proBNP measurements and comprehensive echocardiographic assessments would enhance the understanding of biomarker kinetics in diabetic cardiomyopathy progression.

# 6. CONCLUSION

The findings of the current study demonstrate that NT-proBNP is a superior biomarker than AST for identifying chronic myocardial stress and subclinical cardiac dysfunction in diabetic patients with cardiovascular disease. The concurrent presence of atherogenic dyslipidemia further amplifies cardiovascular risk in this population. These results support the integration of NT-proBNP assessment into routine diabetic care protocols, alongside comprehensive lipid profile management, to facilitate early risk stratification and the implementation of preventive interventions. Such an approach may ultimately reduce the burden of cardiovascular complications in this high-risk diabetic cohort, aligning with contemporary guidelines that emphasize biomarker-guided cardiovascular risk assessment and management.

## 7. Data availability

The numerical data generated during this research are available from the authors.

## 8. Conflict of interest

All authors declare that there was no conflict of interest.

## 9. Funding

The study utilized the hospital resources only, and no external or industry funding was involved.

## 10. Authors' contribution

AAB: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft Preparation, Supervision

FAJ: Validation, Investigation, Data Curation, Writing – Review & Editing

 

WAA: Software, Resources, Visualization, Project Administration, Funding Acquisition

# 11. REFERENCES


1. Savvopoulos S, Hatzikirou H, Jelinek HF. Comparative Analysis of Biomarkers in Type 2 Diabetes Patients With and Without Comorbidities: Insights Into the Role of Hypertension and Cardiovascular Disease. Biomark Insights. 2024;19:11–7. [PubMed] DOI: 10.1177/11772719231222111
2. Hamzah ARAA. The correlation between type 2 diabetes mellitus and hypertension in Iraqi patients. J Med Chem Sci. 2023;6(4):778–88. DOI: 10.26655/JMCHEMSCI.2023.4.9
3. Sena CM, Pereira AM, Seiça R. Endothelial dysfunction - a major mediator of diabetic vascular disease. Biochim Biophys Acta. 2013;1832(12):2216–31. [PubMed] DOI: 10.1016/j.bbadis.2013.08.006
4. Shen J, Zhang J, Wen J, Ming Q, Zhang J, Xu Y. Correlation of serum alanine aminotransferase and aspartate aminotransferase with coronary heart disease. Int J Clin Exp Med. 2015;8(3):4399–404. [PubMed]
5. Kumric M, Ticinovic Kurir T, Borovac JA, Bozic J. Role of novel biomarkers in diabetic cardiomyopathy. World J Diabetes. 2021;12(6):685–705. [PubMed] DOI: 10.4239/wjd.v12.i6.685
6. Lam T, Burns K, Dennis M, Cheung NW, Gunton JE. Assessment of cardiovascular risk in diabetes: Risk scores and provocative testing. World J Diabetes. 2015;6(4):634–41. [PubMed] DOI: 10.4239/wjd.v6.i4.634
7. Landolfo M, Spannella F, Giulietti F, Ortensi B, Stella L, Carlucci MA, et al. Detecting heart stress using NT-proBNP in patients with type 2 diabetes mellitus and hypertension or high-normal blood pressure: a cross-sectional multicentric study. Cardiovasc Diabetol. 2024;23(1):297. [PubMed] DOI: 10.1186/s12933-024-02391-z
8. Camm AJ, Sabbour H, Schnell O, Summaria F, Verma A. Managing thrombotic risk in patients with diabetes. Cardiovasc Diabetol. 2022;21(1):160. [PubMed] DOI: 10.1186/s12933-022-01581-x
9. Fringu FI, Sitar-Taut A V, Caloian B, Zdrenghea D, Comsa D, Gusetu G, et al. The role of nt pro-bnp in the evaluation of diabetic patients with heart failure. Acta endocrinol (buchar). 2020;16(2):183–91. [PubMed] DOI: 10.4183/aeb.2020.183
10. Alredha RDA, Haddawi KH, Hussein FI. Assessing hs-Troponin T and NT-proBNP in Acute Heart Failure and Cardiorenal Syndrome: Diagnostic, Prognostic, and Functional Interrelationships. Acta Marisiensis Sereria Medica. 2025;71(3). DOI: 10.2478/amma-2025-0024
11. McKie PM, Burnett JC Jr. NT-proBNP: The Gold Standard Biomarker in Heart Failure. J Am Coll Cardiol. 2016;68(22):2437–9. [PubMed] DOI: 10.1016/j.jacc.2016.10.001
12. Yokoyama M, Watanabe T, Otaki Y, Takahashi H, Arimoto T, Shishido T, et al. Association of the Aspartate Aminotransferase to Alanine Aminotransferase Ratio with BNP Level and Cardiovascular Mortality in the General Population: The Yamagata Study 10-Year Follow-Up. Dis Markers. 2016;2016:4857917. [PubMed] DOI: 10.1155/2016/4857917
13. Marwick TH, Ritchie R, Shaw JE, Kaye D. Implications of Underlying Mechanisms for the Recognition and Management of Diabetic Cardiomyopathy. J Am Coll Cardiol. 2018;71(3):339–51. [PubMed] DOI: 10.1016/j.jacc.2017.11.019
14. Deng J, Yan F, Tian J, Qiao A, Yan D. Potential clinical biomarkers and perspectives in diabetic cardiomyopathy. Diabetol Metab Syndr. 2023;15(1):35. [PubMed] DOI: 10.1186/s13098-023-00998-y
15. Jia G, Hill MA, Sowers JR. Diabetic Cardiomyopathy: An Update of Mechanisms Contributing to This Clinical Entity. Circ Res. 2018;122(4):624–38. [PubMed] DOI: 10.1161/CIRCRESAHA.117.311586
16. Bayes-Genis A, Docherty KF, Petrie MC, Januzzi JL, Mueller C, Anderson L, et al. Practical algorithms for early diagnosis of heart failure and heart stress using NT-proBNP: A clinical consensus statement from the Heart Failure Association of the ESC. Eur J Heart Fail. 2023;25(11):1891–8. [PubMed] DOI: 10.1002/ejhf.3036
17. Ianoș RD, Cozma A, Lucaciu RL, Hangan AC, Negrean V, Mercea DC, et al. Role of Circulating Biomarkers in Diabetic Cardiomyopathy. Biomedicines. 2024;12(9):2153. [PubMed] DOI: 10.3390/biomedicines12092153
18. Neves JS, Baptista R, Azevedo de Pape E, Rodrigues Pereira M, Paulos R, Pinheiro dos Santos J, et al. Recommendations for the use of natriuretic peptides for early diagnosis of heart disease in patients with diabetes: A consensus report by SPEDM, SPC, NEDM-SPMI and APMGF. Rev Port Cardiol. 2025;44(1):57–67. [PubMed] DOI: 10.1016/j.repc.2024.07.010
19. Baba M, Yoshida K, Ieda M. Clinical Applications of Natriuretic Peptides in Heart Failure and Atrial Fibrillation. Int J Mol Sci. 2019;20(11):2824. [PubMed] DOI: 10.3390/ijms20112824
20. Gerstein HC, Colhoun HM, Dagenais GR, Diaz R, Lakshmanan M, Pais P, et al. Dulaglutide and cardiovascular outcomes in type 2 diabetes (REWIND): a double-blind, randomised placebo-controlled trial. Lancet. 2019;394(10193):121–30. [PubMed] DOI: 10.1016/S0140-6736(19)31149-3
21. Kristensen SL, Preiss D, Jhund PS, Squire I, Cardoso JS, Merkely B, et al. Risk Related to Pre–Diabetes Mellitus and Diabetes Mellitus in Heart Failure With Reduced Ejection Fraction. Circ Heart Fail. 2016;9(1):e002560. [PubMed] DOI: 10.1161/CIRCHEARTFAILURE.115.002560


 

22. Fang M, Wang D, Tang O, McEvoy JW, Echouffo-Tcheugui JB, Christenson RH, et al. Subclinical Cardiovascular Disease in US Adults With and Without Diabetes. J Am Heart Assoc. 2023;12(11):e029083. [PubMed] DOI: 10.1161/JAHA.122.029083

23. Ndrepepa G. Aspartate aminotransferase and cardiovascular disease—a narrative review. J Lab Precis Med. 2021;6:12. DOI: 10.21037/jlpm-20-93

24. Cao Z, Jia Y, Zhu B. BNP and NT-proBNP as Diagnostic Biomarkers for Cardiac Dysfunction in Both Clinical and Forensic Medicine. Int J Mol Sci. 2019;20(8):1820. [PubMed] DOI: 10.3390/ijms20081820

25. Hirano T. Pathophysiology of Diabetic Dyslipidemia. J Atheroscler Thromb. 2018;25(9):771–82. [PubMed] DOI: 10.5551/jat.RV17023

26. Bhowmik B, Siddiquee T, Mujumder A, Afsana F, Ahmed T, Mdala IA, et al. Serum Lipid Profile and Its Association with Diabetes and Prediabetes in a Rural Bangladeshi Population. Int J Environ Res Public Health. 2018;15(9):1944. [PubMed] DOI: 10.3390/ijerph15091944

27. Mohamed RAA, Noor BYM, Ahmed SM, Dafalla AM, Mohammed YA, Modawe GO. Assessment of Lipid Profile among Sudanese patients with Type 2 Diabetes Mellitus. Al-Kindy Coll Med J. 2022;18(1):30–5. DOI: 10.47723/kcmj.v18i1.422

28. Artha IMJR, Bhargah A, Dharmawan NK, Pande UW, Triyana KA, Mahariski PA, et al. High level of individual lipid profile and lipid ratio as a predictive marker of poor glycemic control in type-2 diabetes mellitus. Vasc Health Risk Manag. 2019;15:149–57. [PubMed] DOI: 10.2147/VHRM.S209830

29. Rosenson RS, Brewer HB, Davidson WS, Fayad ZA, Fuster V, Goldstein J, et al. Cholesterol Efflux and Atheroprotection. Circulation. 2012;125(15):1905–19. [PubMed] DOI: 10.1161/CIRCULATIONAHA.111.066589

30. März W, Kleber ME, Scharnagl H, Speer T, Zewinger S, Ritsch A, et al. HDL cholesterol: reappraisal of its clinical relevance. Clin Res Cardiol. 2017;106(9):663–75. [PubMed] DOI: 10.1007/s00392-017-1106-1

31. Balling M, Afzal S, Varbo A, Langsted A, Davey Smith G, Nordestgaard BG. VLDL Cholesterol Accounts for One-Half of the Risk of Myocardial Infarction Associated With apoB-Containing Lipoproteins. J Am Coll Cardiol. 2020;76(23):2725–35. [PubMed] DOI: 10.1016/j.jacc.2020.09.610

32. Bhatt DL, Steg PG, Miller M, Brinton EA, Jacobson TA, Ketchum SB, et al. Cardiovascular Risk Reduction with Icosapent Ethyl for Hypertriglyceridemia. N Engl J Med. 2019;380(1):11–22. [PubMed] DOI: 10.1056/NEJMoa1812792

33. Ahmed HS, Mohammed MS. Atherogenic Indices in Type 2 Diabetic Iraqi Patients and Its Association with Cardiovascular Disease Risk. J Fac Med Baghdad. 2023;65(3):179–86. DOI: 10.32007/jfacmedbagdad.2075

34. Siddiqui MH, Dixit R, Agarwal S, Jha SC, Khanna H, Agrawal SK. Determining the role of NT-proBNP levels in diabetic patients with heart failure: A study from North India. J Educ Health Promot. 2024;13:20. [PubMed] DOI: 10.4103/jehp.jehp_701_23

35. Abdulaziz LS, Khazaal FAK. Residual cardiovascular risk in diabetes and obesity: Targeting lipid abnormalities other than LDL cholesterol. Al-Kindy Coll Med J. 2020;11(1):1–5. Full Text

36. Endo Y, Fujita M, Ikewaki K. HDL Functions—Current Status and Future Perspectives. Biomolecules. 2023;13(1):105. [PubMed] DOI: 10.3390/biom13010105

37. Femlak M, Gluba-Brzózka A, Ciałkowska-Rysz A, Rysz J. The role and function of HDL in patients with diabetes mellitus and the related cardiovascular risk. Lipids Health Dis. 2017;16(1):207. [PubMed] DOI: 10.1186/s12944-017-0594-3

38. Cosentino F, Grant PJ, Aboyans V, Bailey CJ, Ceriello A, Delgado V, et al. 2019 ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD. Eur Heart J. 2020;41(2):255–323. [PubMed] DOI: 10.1093/eurheartj/ehz486

39. American Diabetes Association. 10. Cardiovascular Disease and Risk Management: Standards of Medical Care in Diabetes—2022. Diabetes Care. 2022;45(Suppl 1):S144–74. DOI: 10.2337/dc22-S010

 