

Assessment of Left Atrial Function in Atrial Fibrillation Patients with Diabetes Mellitus

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ABSTRACT

Background: Atrial fibrillation and diabetes mellitus commonly coexist and may accelerate left atrial remodeling, cause impaired atrial function (CHADS2 score, CHA2DS2-VASc score, NT-proBNP) and increase cardiovascular risk. **Methods & Materials:** This cross-sectional study was conducted at the Department of Medicine, Uttara Adhunik Medical College Hospital, Dhaka, Bangladesh from 16 March 2025 to 15 March 2026. The study included 120 adult patients with atrial fibrillation and diabetes mellitus. Data were analyzed using SPSS version 26.0, with $p < 0.05$ considered statistically significant. **Results:** Among 120 atrial fibrillation patients with diabetes mellitus, the mean age was 61.8 ± 9.6 years, and 65.0% were male. Hypertension was present in 76.7%, and uncontrolled diabetes, $HbA1c \geq 7.0\%$, was observed in 71.7%. The mean CHADS2 and CHA2DS2-VASc scores were 2.8 ± 1.2 and 4.1 ± 1.4 , respectively, while the median NT-proBNP level was 860 pg/mL, IQR 420–1850. Impaired left atrial function was found in 82 patients (68.3%). Compared with preserved LA function, impaired LA function was associated with older age (64.1 ± 9.2 vs 56.9 ± 7.8 years), longer diabetes duration (10.4 ± 5.2 vs 6.8 ± 3.9 years), higher $HbA1c$ ($8.6 \pm 1.5\%$ vs $7.4 \pm 1.1\%$), higher CHA2DS2-VASc score (4.5 ± 1.3 vs 3.2 ± 1.1), higher NT-proBNP (1280 vs 410 pg/mL), larger LAVI (46.9 ± 10.7 vs 33.4 ± 6.8 mL/m²), and lower LA reservoir strain ($12.7 \pm 4.2\%$ vs $22.4 \pm 3.7\%$), all statistically significant. Increased LAVI ≥ 34 mL/m², OR of 5.64 (95% CI 2.15–14.79, $p < 0.001$) and NT-proBNP ≥ 900 pg/mL, OR 4.21 (95% CI 1.82–9.74, $p = 0.001$) were the strongest independent predictors of impaired LA function. **Conclusion:** Impaired left atrial function was

common among atrial fibrillation patients with diabetes mellitus and was associated with higher CHADS2 and CHA2DS2-VASc scores, raised NT-proBNP, poor glycemic control, longer diabetes duration, and increased left atrial volume.

Keywords: Atrial fibrillation; Diabetes mellitus; Left atrial function; CHA2DS2-VASc score; and NT-proBNP.

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INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia and is increasingly recognized as a major contributor to stroke, heart failure, hospitalization, impaired quality of life, and premature mortality. Its burden is rising globally because of population ageing, hypertension, diabetes mellitus, obesity, chronic kidney disease, and improved survival from cardiovascular disease. Recent Global Burden of Disease estimates showed that atrial fibrillation and atrial flutter affected approximately 52.6 million people worldwide in 2021, with increasing absolute numbers of cases, deaths, and disability-adjusted life years since 1990 [1]. In Southeast Asia and South Asia, the reported prevalence of AF is often lower than in Western populations, but the absolute burden is substantial due to large population sizes, aging demographics, limited screening, and variable access to anticoagulation and rhythm-control services [2]. Diabetes mellitus is another rapidly expanding public health problem. A pooled global analysis reported a major rise in adult diabetes prevalence from 1990 to 2022, with the greatest treatment gaps in low- and middle-income countries [3]. Bangladesh is facing this epidemiological transition

acutely. Systematic review evidence has shown a considerable burden of diabetes and prediabetes in Bangladesh, while nationally representative analyses reported diabetes in about 10% of Bangladeshi adults in 2017–2018, with higher prevalence in older age groups and important socioeconomic disparities in awareness and management [4,5]. Local hospital-based evidence also indicates that AF remains clinically important in Bangladesh, with one Dhaka-based study of hospitalized AF patients showing frequent structural heart disease, stroke presentation, and underuse of anticoagulation [6]. The coexistence of AF and diabetes has important pathophysiological and clinical implications. Diabetes contributes to atrial electrical and structural remodeling through hyperglycemia, insulin resistance, oxidative stress, inflammation, autonomic dysfunction, endothelial dysfunction, and myocardial fibrosis. These mechanisms may promote atrial enlargement, impaired atrial compliance, and persistence of AF. Large cohort evidence has shown that type 2 diabetes is associated with a higher risk of AF, particularly in patients with poor glycemic control and renal dysfunction [7]. A systematic review and meta-analysis also suggested that diabetes is associated with a

greater likelihood of non-paroxysmal AF and progression toward more sustained AF patterns [8]. Left atrial (LA) function has emerged as a sensitive marker of atrial remodeling beyond simple LA size. Conventional echocardiography can measure LA diameter and LA volume index, but speckle-tracking echocardiography can evaluate LA reservoir, conduit, and contractile function. In AF, LA reservoir strain is especially relevant because atrial contractile function is often absent or unreliable during irregular rhythm. LA strain has been linked with atrial fibrosis, AF burden, recurrence, stroke risk, and adverse cardiovascular outcomes [9,10]. Clinical risk scores such as CHADS2 and CHA2DS2-VASc remain central for thromboembolic risk stratification, but they do not directly quantify atrial mechanical dysfunction. Evidence suggests that the CHA2DS2-VASc score correlates with LA size among AF patients, supporting the biological link between clinical risk burden and atrial remodeling [11]. NT-proBNP is another clinically relevant biomarker in this context. It reflects myocardial wall stress and may be elevated in AF, heart failure, renal dysfunction, and advanced atrial remodeling. Recent studies have shown that NT-proBNP is a useful marker for prevalent

and incident AF, although interpretation requires caution because AF itself can raise NT-proBNP independently of overt heart failure [12]. Therefore, combining echocardiographic LA functional assessment with the CHADS2, CHA2DS2-VASc, and NT-proBNP scores may provide a more comprehensive understanding of cardiovascular risk in diabetic AF patients. Despite growing international evidence, there is limited Bangladeshi data on LA functional impairment among patients who have both AF and diabetes mellitus. Most local studies describe AF etiology, clinical presentation, or anticoagulation practice, but few integrate advanced echocardiographic LA function, diabetes-related variables, stroke-risk scores, and NT-proBNP. This creates an important evidence gap for risk stratification in tertiary care settings in Bangladesh. Therefore, the present study aimed to assess left atrial function in patients with atrial fibrillation and diabetes mellitus and to evaluate its relationship with CHADS2 score, CHA2DS2-VASc score, NT-proBNP level, glycemic status, and selected clinical and echocardiographic parameters.

METHODS & MATERIALS

This cross-sectional observational study was conducted in the Department of Medicine, Uttara Adhunik Medical College Hospital, Dhaka, Bangladesh., over a defined study period of 1 year from 16 March 2025 to 15 March 2026. Adult patients aged ≥18 years with documented atrial fibrillation and diagnosed diabetes mellitus were enrolled by purposive sampling after obtaining written informed consent. Atrial fibrillation was confirmed by 12-lead electrocardiography or previous medical records, and diabetes mellitus was defined by a history of physician-diagnosed diabetes, use of antidiabetic medication, or

laboratory evidence according to standard diagnostic criteria. Patients with significant valvular heart disease, congenital heart disease, acute coronary syndrome, severe renal failure, active infection, malignancy, poor echocardiographic window, or unwillingness to participate were excluded. A total of 120 patients were included. Data were collected using a structured data collection sheet. Socio-demographic information, cardiovascular risk factors, duration and type of atrial fibrillation, duration of diabetes, treatment history, smoking status, blood pressure, body mass index, and relevant comorbidities were recorded. Laboratory investigations included fasting blood glucose, HbA1c, serum creatinine, estimated glomerular filtration rate, fasting lipid profile, and NT-proBNP. NT-proBNP levels were measured from venous blood samples using the hospital laboratory method and expressed in pg/mL. Stroke risk was assessed using both the CHADS2 and CHA2DS2-VASc scores. For the CHADS2 score, congestive heart failure, hypertension, age ≥75 years, diabetes mellitus, and previous stroke or TIA were recorded. For the CHA2DS2-VASc score, congestive heart failure, hypertension, age, diabetes mellitus, stroke/TIA, vascular disease, sex, and age were assessed. Patients were then categorized according to their score distribution. All participants underwent transthoracic echocardiography by an experienced cardiologist using standard echocardiographic views. Left ventricular ejection fraction, left atrial diameter, left atrial volume index, E/e' ratio, pulmonary artery systolic pressure, and other relevant parameters were measured. Left atrial function was assessed using left atrial reservoir strain, conduit strain, emptying fraction, stiffness index, and left atrial volume index. Patients were classified as

having preserved or impaired left atrial function based on predefined echocardiographic criteria. Data were analyzed using SPSS (V 26.0). Quantitative variables were expressed as mean ± SD or median with interquartile range, and categorical variables as frequency and percentage. Independent t-test, Mann-Whitney U test, Chi-square test, Pearson or Spearman correlation, and logistic regression analysis were applied as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

Among 120 atrial fibrillation patients with diabetes mellitus, the mean age was 61.8 ± 9.6 years, and 76 patients, 63.3%, were aged 60 years or above. Male predominance was observed: 78 males (65.0%) and 42 females (35.0%). The mean BMI was 26.4 ± 3.8 kg/m², and 72 patients (60.0%) were overweight or obese. The mean duration of diabetes mellitus was 9.3 ± 5.1 years, while 52 patients (43.3%) had diabetes for 10 years or more. Glycemic control was poor in most patients: 86 (71.7%) had HbA1c ≥7.0%, with a mean HbA1c of 8.2 ± 1.5%. Regarding atrial fibrillation pattern, persistent AF was the most common type, found in 48 patients (40.0%), followed by permanent AF in 42 patients (35.0%) and paroxysmal AF in 30 patients (25.0%). Hypertension was the most frequent comorbidity, present in 92 patients (76.7%), followed by ischemic heart disease in 49 patients (40.8%), heart failure in 34 patients (28.3%), chronic kidney disease in 22 patients (18.3%), and previous stroke or TIA in 18 patients (15.0%). Current anticoagulant use was observed in 71 patients (59.2%) *Table I*.

Table I
Baseline socio-demographic and clinical characteristics of the study participants (n=120).

Variables	Category	n (%)
Age (years)	Mean ± SD	61.8 ± 9.6
	≥60 years	76 (63.3%)
Gender	Male	78 (65.0%)
	Female	42 (35.0%)
BMI (kg/m²)	Mean ± SD	26.4 ± 3.8
	Overweight/obese	72 (60.0%)
Duration of diabetes mellitus	Duration of diabetes mellitus, years	9.3 ± 5.1
	Duration of DM ≥10 years	52 (43.3%)
HbA1c (%)	Mean ± SD	8.2 ± 1.5
	Uncontrolled diabetes (HbA1c ≥7.0%)	86 (71.7%)
Duration of atrial fibrillation (years)	Mean ± SD	3.6 ± 2.8
	Paroxysmal AF	30 (25.0%)
Type of atrial fibrillation	Persistent AF	48 (40.0%)
	Permanent AF	42 (35.0%)
	Hypertension	92 (76.7%)
Clinical variables	Ischemic heart disease	49 (40.8%)
	Heart failure	34 (28.3%)
	Previous stroke/TIA	18 (15.0%)
	Chronic kidney disease	22 (18.3%)
	Current anticoagulant use	71 (59.2%)

The mean CHADS2 score was 2.8 ± 1.2 . Most patients had moderate to high CHADS2 scores. CHADS2 score 2 was observed in 38 patients (31.7%), score 3 in 34 patients (28.3%), and score ≥ 4 in 30 patients (25.0%). Only 18 patients (15.0%) had a CHADS2 score of 1. The mean CHA2DS2-VASc score was 4.1 ± 1.4 . Most patients had high thromboembolic risk. Score 3–4 was found in 55 patients (45.8%), while score ≥ 5 was found in 43 patients (35.8%). Only 22 patients (18.3%) had a score of 1–2 (*Table II*).

Table II
Distribution of participants according to CHADS2 and CHA2DS2-VASc scores ($n=120$).

Variables	Category	n (%)
CHADS2 score	Score 1	18 (15.0%)
	Score 2	38 (31.7%)
	Score 3	34 (28.3%)
	Score ≥ 4	30 (25.0%)
	Mean $\pm$ SD	2.8 ± 1.2
CHA2DS2-VASc score	Score 1–2	22 (18.3%)
	Score 3–4	55 (45.8%)
	Score ≥ 5	43 (35.8%)
	Mean $\pm$ SD	4.1 ± 1.4

The mean fasting blood glucose was 9.4 ± 2.8 mmol/L, and the mean HbA1c was $8.2 \pm 1.5\%$, indicating poor glycemic control among the study participants. The mean serum creatinine was 1.18 ± 0.42 mg/dL, and the mean eGFR was 68.5 ± 18.7 mL/min/1.73 m², suggesting that mild renal impairment was common. The lipid profile showed a mean total cholesterol of 184.6 ± 42.3 mg/dL, LDL cholesterol of 112.8 ± 34.9 mg/dL, HDL cholesterol of 38.7 ± 8.6 mg/dL, and triglycerides of 178.4 ± 72.5 mg/dL. The median NT-proBNP level was 860 pg/mL, with an interquartile range of 420–1850 pg/mL (*Table III*).

Table III
Laboratory profile of the study participants ($n=120$).

Laboratory parameters	Mean $\pm$ SD / Median (IQR)
Fasting blood glucose (mmol/L)	9.4 ± 2.8
HbA1c (%)	8.2 ± 1.5
Serum creatinine (mg/dL)	1.18 ± 0.42
eGFR (mL/min/1.73 m ²)	68.5 ± 18.7
Total cholesterol (mg/dL)	184.6 ± 42.3
LDL cholesterol (mg/dL)	112.8 ± 34.9
HDL cholesterol (mg/dL)	38.7 ± 8.6
Triglyceride (mg/dL)	178.4 ± 72.5
NT-proBNP (pg/mL)	860 (420–1850)

The mean left ventricular ejection fraction was $52.8 \pm 8.6\%$, indicating that overall systolic function was relatively preserved, although some patients had reduced function. The mean left atrial diameter was 43.6 ± 6.4 mm, and the mean left atrial volume index, LAVI, was 42.6 ± 11.8 mL/m², suggesting left atrial enlargement. The mean E/e' ratio was 14.8 ± 4.9 , indicating elevated left ventricular filling pressure in many patients. The mean pulmonary artery systolic pressure was 38.2 ± 10.7 mmHg. Regarding left atrial function, the mean LA reservoir strain was $15.8 \pm 6.1\%$, the mean LA conduit strain was $8.9 \pm 3.8\%$, the mean LA emptying fraction was $27.4 \pm 9.6\%$, and the mean LA stiffness index was 1.12 ± 0.54 . Preserved LA function was observed in 38 patients (31.7%), while impaired LA function was observed in 82 patients (68.3%) (*Table IV*).

Table IV
Echocardiographic and left atrial functional parameters ($n=120$).

Echocardiographic parameters	n (%) / Mean $\pm$ SD
Left ventricular ejection fraction (%)	52.8 ± 8.6
Left atrial diameter (mm)	43.6 ± 6.4
Left atrial volume index (mL/m ²)	42.6 ± 11.8
E/e' ratio	14.8 ± 4.9
Pulmonary artery systolic pressure (mmHg)	38.2 ± 10.7
LA reservoir strain (%)	15.8 ± 6.1
LA conduit strain (%)	8.9 ± 3.8
LA emptying fraction (%)	27.4 ± 9.6
LA stiffness index	1.12 ± 0.54
Preserved LA function	38 (31.7%)
Impaired LA function	82 (68.3%)

Patients with impaired LA function were significantly older than those with preserved LA function (64.1 ± 9.2 years vs 56.9 ± 7.8 years, $p<0.001$). They also had a longer duration of diabetes (10.4 ± 5.2 years vs 6.8 ± 3.9 years; $p<0.001$) and poorer glycemic control (HbA1c $8.6 \pm 1.5\%$ vs $7.4 \pm 1.1\%$; $p<0.001$). The duration of AF was also significantly longer in the impaired LA function group, 4.3 ± 2.9 years vs 2.1 ± 1.6 years, $p<0.001$. The impaired LA function group had higher CHADS2 scores (3.1 ± 1.2

vs 2.1 ± 0.9 , $p<0.001$) and higher CHA2DS2-VASc scores (4.5 ± 1.3 vs 3.2 ± 1.1 , $p<0.001$). NT-proBNP was also markedly higher among patients with impaired LA function (1280 pg/mL, IQR 650–2420) compared with those with normal LA function (410 pg/mL, IQR 220–790), $p<0.001$. Echocardiographically, impaired LA function was associated with lower LVEF ($51.3 \pm 8.7\%$ vs $56.1 \pm 7.2\%$, $p=0.004$), higher LAVI (46.9 ± 10.7 vs 33.4 ± 6.8 mL/m², $p<0.001$), lower LA reservoir strain ($12.7 \pm 4.2\%$ vs $22.4 \pm 3.7\%$, $p<0.001$), and higher LA stiffness index (1.35 ± 0.48 vs 0.65 ± 0.24 , $p<0.001$) *Table V*.

Table V
Comparison of clinical, biochemical, and echocardiographic variables according to left atrial function.

Variables	Preserved LA function (n=38)	Impaired LA function (n=82)	p-value
	Mean $\pm$ SD / Median (IQR)		
Age (years)	56.9 $\pm$ 7.8	64.1 $\pm$ 9.2	<0.001
Duration of DM (years)	6.8 $\pm$ 3.9	10.4 $\pm$ 5.2	<0.001
HbA1c (%)	7.4 $\pm$ 1.1	8.6 $\pm$ 1.5	<0.001
Duration of AF (years)	2.1 $\pm$ 1.6	4.3 $\pm$ 2.9	<0.001
CHADS2 score	2.1 $\pm$ 0.9	3.1 $\pm$ 1.2	<0.001
CHA2DS2-VASc score	3.2 $\pm$ 1.1	4.5 $\pm$ 1.3	<0.001
NT-proBNP (pg/mL)	410 (220–790)	1280 (650–2420)	<0.001
LVEF (%)	56.1 $\pm$ 7.2	51.3 $\pm$ 8.7	0.004
LAVI (mL/m ²)	33.4 $\pm$ 6.8	46.9 $\pm$ 10.7	<0.001
LA reservoir strain (%)	22.4 $\pm$ 3.7	12.7 $\pm$ 4.2	<0.001
LA stiffness index	0.65 $\pm$ 0.24	1.35 $\pm$ 0.48	<0.001

The CHADS2 score showed a moderate negative correlation with LA reservoir strain ($r = -0.46$; $p < 0.001$) and positive correlations with LA stiffness index ($r = 0.42$; $p < 0.001$) and LAVI ($r = 0.39$; $p < 0.001$). The CHA2DS2-VASc score showed a stronger negative correlation with LA reservoir strain ($r = -0.51$; $p < 0.001$) and positive correlations with LA stiffness index ($r = 0.48$; $p < 0.001$) and LAVI ($r = 0.45$; $p < 0.001$). NT-proBNP had the strongest relationship with LA functional parameters. It showed a negative correlation with LA reservoir strain ($r = -0.58$) and positive correlations with LA stiffness index ($r = 0.61$) and LAVI ($r = 0.54$), all $p<0.001$. HbA1c also showed significant correlations with LA reservoir strain ($r = -0.34$), LA stiffness index ($r = 0.30$), and LAVI ($r = 0.28$, $p = 0.001$). The duration of diabetes showed significant, similar correlations with LA reservoir strain ($r = -0.37$), LA stiffness index ($r = 0.35$), and LAVI ($r = 0.31$; $p<0.001$) *Table VI*.

Table VI
Correlation of left atrial functional parameters with clinical risk scores and NT-proBNP.

Variables	LA reservoir strain (r)	LA stiffness index (r)	LAVI (r)	p-value
CHADS2 score	-0.46	0.42	0.39	<0.001
CHA2DS2-VASc score	-0.51	0.48	0.45	<0.001
NT-proBNP	-0.58	0.61	0.54	<0.001
HbA1c	-0.34	0.3	0.28	0.001
Duration of DM	-0.37	0.35	0.31	<0.001

On multivariable logistic regression analysis, several factors were independently associated with impaired LA function. The strongest predictor was increased LAVI ≥ 34 mL/m², with an adjusted OR of 5.64 (95% CI 2.15–14.79, $p<0.001$). Raised NT-proBNP ≥ 900 pg/mL was also a strong predictor, with adjusted OR 4.21 (95% CI 1.82–9.74, $p=0.001$). CHA2DS2-VASc score ≥ 4 increased the odds of impaired LA function by about three times (adjusted OR 3.15, 95% CI 1.39–7.15, $p=0.006$). CHADS2 score ≥ 3 was also significant, adjusted OR 2.72 (95% CI 1.20–6.17, $p=0.017$). Other significant predictors included HbA1c $\geq 7.0\%$, adjusted OR 2.74 ($p=0.019$); duration of AF ≥ 3 years, adjusted OR 2.68 ($p=0.012$); duration of diabetes ≥ 10 years, adjusted OR 2.31 ($p=0.031$); and age ≥ 60 years, adjusted OR 2.12 ($p=0.047$) *Table VII*.

Table VII
Predictors of impaired left atrial function among AF patients with diabetes mellitus.

Variables	Adjusted OR	95% CI	p-value
Age ≥ 60 years	2.12	1.01–4.46	0.047
Duration of DM ≥ 10 years	2.31	1.08–4.94	0.031
HbA1c $\geq 7.0\%$	2.74	1.18–6.37	0.019
Duration of AF ≥ 3 years	2.68	1.24–5.79	0.012
CHADS2 score ≥ 3	2.72	1.20–6.17	0.017
CHA2DS2-VASc score ≥ 4	3.15	1.39–7.15	0.006
NT-proBNP ≥ 900 pg/mL	4.21	1.82–9.74	0.001
LAVI ≥ 34 mL/m ²	5.64	2.15–14.79	<0.001

DISCUSSION
In this hospital-based study of 120 atrial fibrillation patients with diabetes mellitus, impaired left atrial (LA) function was common, affecting 82 patients (68.3%). The study population had a high cardiometabolic risk profile, with a mean age of 61.8 ± 9.6 years, male predominance 65.0%, hypertension 76.7%, overweight/obesity 60.0%, uncontrolled diabetes 71.7%, and a median NT-proBNP of 860 pg/mL. These characteristics are clinically important

because diabetes, hypertension, obesity, and AF act together to promote atrial fibrosis, pressure overload, and electrical remodeling. The mean LA reservoir strain in this study was $15.8 \pm 6.1\%$, markedly lower than the normal pooled reservoir strain of about 39% reported by Pathan et al. and lower than the Copenhagen City Heart Study reference median PALS of 39.4% [13,14]. This supports the presence of substantial atrial mechanical dysfunction in the present cohort. The observed mean LAVI of $42.6 \pm 11.8 \text{ mL/m}^2$ and impaired LA function rate of 68.3% align with previous evidence linking diabetes to LA enlargement and dysfunction that extends beyond conventional diastolic dysfunction. For example, Kadappu et al. found LA enlargement in diabetes independent of hypertension and diastolic function, while Graça et al. demonstrated LA dysfunction in asymptomatic type 2 diabetes using cardiac MRI [15,16]. In addition, Gulmez et al. observed that LA dysfunction can occur within six months of diabetes diagnosis, and Li et al. confirmed the utility of real-time 3D echocardiography in detecting LA volume and functional changes in type 2 diabetes [17,18]. It is important to note that the higher impairment in our study is anticipated, given that all patients had both AF and diabetes, with most also having hypertension. Our LA strain values were also lower than those reported in diabetic patients without AF. Dang et al. found lower LA reservoir strain in Vietnamese patients with type 2 diabetes compared with healthy controls, approximately 31.2% vs 38.75%, and lower conduit strain, 14.77% vs 19.58% [19]. In contrast, our mean reservoir strain was 15.8% and conduit strain was 8.9%, suggesting that AF imposes an additional decrement in atrial deformation beyond that observed with diabetes alone. Similarly, Wang et al. reported additive adverse effects of diabetes and hypertension on LA strain, with T2DM plus hypertension independently reducing LASr ($\beta = -3.931$) and LAScd ($\beta = -3.781$) [20]. This is highly relevant to the present study, where 76.7% had hypertension. Nabati et al. reported higher LAVI in diabetic patients than in controls (43.05 vs 29.10 mL/m^2), which closely matches our mean LAVI of 42.6 mL/m^2 [21]. The relationship between LA dysfunction and stroke-risk scores was also clinically meaningful in our cohort. The mean CHADS2 score was 2.8 ± 1.2 , and the mean CHA2DS2-VASc score was 4.1 ± 1.4 . Patients with impaired LA function had higher CHADS2 scores (3.1 ± 1.2 vs 2.1 ± 0.9 ; $p < 0.001$) and CHA2DS2-VASc scores (4.5 ± 1.3 vs 3.2 ± 1.1 ; $p < 0.001$). These findings are supported by the ENGAGE AF-TIMI 48 echocardiographic sub-study, which reported that 55% of AF patients had both LA enlargement and reduced LA emptying fraction, and that higher CHADS2

scores were associated with larger LA size and lower LA function [22]. Furthermore, Tsai et al. followed 708 AF patients for more than 15 years and found both CHA2DS2-VASc score and LA size correlated with stroke/TIA; the correlation between LA size and CHA2DS2-VASc was weak but significant ($r=0.17$, $p<0.0001$) [11]. Our stronger correlation between CHA2DS2-VASc and LAVI ($r=0.45$) may reflect the inclusion of high-risk diabetic patients with heavy hypertension and AF burden. Additionally, NT-proBNP showed the strongest association with LA dysfunction. Median NT-proBNP was 1280 pg/mL in impaired LA function, compared with 410 pg/mL in preserved LA function ($p<0.001$). NT-proBNP correlated negatively with LA reservoir strain ($r = -0.58$; $p < 0.001$) and positively with LA stiffness index ($r = 0.61$; $p < 0.001$). These results are consistent with those of Hijazi et al. in ARISTOTLE, who reported that NT-proBNP quartiles ranged from $\leq 363 \text{ ng/L}$ to $>1250 \text{ ng/L}$, with annual stroke/systemic embolism increasing from 0.74% to 2.21%, and cardiac death from 0.86% to 4.14% [23]. Supporting this, Santema et al. also showed that AF itself elevates NT-proBNP, with baseline AF patients having a median NT-proBNP of approximately 2105 pg/mL [24], while Werhahn et al. found that NT-proBNP was a better marker of prevalent and incident AF than heart failure in stable outpatients [12]. Together, these findings suggest that in our study, NT-proBNP probably reflected a mixed burden of AF, atrial stretch, LV filling pressure, and subclinical heart failure. Finally, on regression analysis, increased LAVI $\geq 34 \text{ mL/m}^2$ emerged as the strongest predictor of impaired LA function (adjusted OR 5.64), followed by NT-proBNP $\geq 900 \text{ pg/mL}$ (OR 4.21), CHA2DS2-VASc ≥ 4 (OR 3.15), CHADS2 ≥ 3 (OR 2.72), HbA1c $\geq 7.0\%$ (OR 2.74), and AF duration ≥ 3 years (OR 2.68). These results concur with studies showing that LA structure and risk scores provide complementary information in AF [25,26]. Clinically, these findings indicate that Bangladeshi AF patients with diabetes should not be evaluated solely by rhythm diagnosis and CHA2DS2-VASc, as LA strain, LAVI, and NT-proBNP can help identify patients with advanced atrial myopathy who need closer anticoagulation review, stricter glycemic and blood pressure control, heart failure screening, and more intensive follow-up.

LIMITATIONS

This was a single-center, hospital-based study with a modest sample size, which may limit generalizability. Its cross-sectional design could not establish causality. Purposive sampling may have caused selection bias. Left atrial functional assessment may be influenced by image

quality, heart rate variability, and operator dependency. Long-term outcomes such as stroke, heart failure, hospitalization, and mortality were not evaluated.

CONCLUSION

Impaired left atrial function was common among atrial fibrillation patients with diabetes mellitus. Higher CHADS2 score, higher CHA2DS2-VASc score, raised NT-proBNP, poor glycemic control, longer diabetes duration, and increased left atrial volume were associated with left atrial dysfunction. Assessment of LA function using risk scores and NT-proBNP may help identify high-risk patients who require closer clinical monitoring.

RECOMMENDATIONS

Routine assessment of left atrial function should be considered in atrial fibrillation patients with diabetes mellitus. The CHADS2 score, CHA2DS2-VASc score, and NT-proBNP may be used in combination with echocardiographic parameters to improve risk stratification. Good glycemic control, blood pressure control, appropriate anticoagulation, and regular cardiovascular follow-up should be emphasized. Larger multicenter longitudinal studies are recommended to validate these findings.

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CONFLICT OF INTEREST

None declared

REFERENCES

1. Tan S, Zhou J, Veang T, Lin Q, Liu Q. Global, regional, and national burden of atrial fibrillation and atrial flutter from 1990 to 2021: sex differences and global burden projections to 2046—a systematic analysis of the Global Burden of Disease Study 2021. *Europace*. 2025 Feb;27(2): eua027.
2. Krittayahong R, Kaolawanich Y, Phrommintikul A, Guruparan M, Subaschandran K, Bahuleyan CG, Nambodiri N, Lip GY. The burden of atrial fibrillation and unmet needs of its management in Southeast Asia and South Asia. *The Lancet Regional Health-Southeast Asia*. 2025 Mar 1;34.
3. Zhou B, Rayner AW, Gregg EW, Sheffer KE, Carrillo-Larco RM, Bennett JE, Shaw JE, Paciorek CJ, Singleton RK, Pires AB, Stevens GA. Worldwide trends in diabetes prevalence and treatment from 1990 to 2022: a pooled analysis of 1108 population-representative studies with 141 million participants. *The Lancet*. 2024 Nov 23;404(10467):2077-93.
4. Akhtar S, Nasir JA, Sarwar A, Nasr N, Javed A, Majeed R, Salam MA, Billah B. Prevalence of diabetes and pre-diabetes in Bangladesh: a systematic review and meta-analysis. *BMJ open*. 2020 Sep 1;10(9): e036086.

5. Ahsan KZ, Iqbal A, Jamil K, Haider MM, Khan SH, Chakraborty N, Streatfield PK. Socioeconomic disparities in diabetes prevalence and management among the adult population in Bangladesh. *Plos one*. 2022 Dec 20;17(12):e0279228.
6. Islam AM, Shimu IJ, Rahman MA, Waresuzzaman M, Rahman MS, Ananya KF, Islam MN, Abdullah M, Khoda MM, Zaman S. Clinical profile of atrial fibrillation in hospitalized patients: experience from two tertiary centers of Bangladesh. *BIRDEM Medical Journal*. 2023 Sep 27;13(3):143-8.
7. Seyed Ahmadi S, Svensson AM, Pivodic A, Rosengren A, Lind M. Risk of atrial fibrillation in persons with type 2 diabetes and the excess risk in relation to glycaemic control and renal function: a Swedish cohort study. *Cardiovascular diabetology*. 2020 Jan 18;19(1):9.
8. Aljila F, Buttia C, Reichlin T, Razvi S, Minder B, Wilhelm M, Muka T, Franco OH, Bano A. Association of diabetes with atrial fibrillation types: a systematic review and meta-analysis. *Cardiovascular Diabetology*. 2021 Dec 7;20(1):230.
9. Javadi N, Bismee NN, Abbas MT, Scalia IG, Pereyra M, Baba Ali N, Attaripour Esfahani S, Awad K, Farina JM, Ayoub C, Arsanjani R. Left atrial strain: state of the art and clinical implications. *Journal of personalized medicine*. 2024 Nov 5;14(11):1093.
10. Mauriello A, Correr A, Ascrizzi A, Del Vecchio GE, Benfari G, Ilardi F, Lisi M, Malagoli A, Mandoli GE, Pastore MC, Sperlongano S. Relationship between left atrial strain and atrial fibrillation: the role of stress echocardiography. *Diagnostics*. 2024 Dec 24;15(1):7.
11. Tsai CF, Huang PS, Chen JJ, Chang SN, Chiu FC, Lin TT, Lai LP, Hwang JJ, Tsai CT. Correlation between CHA2DS2-VASc score and left atrial size in patients with atrial fibrillation: a more than 15-year prospective follow-up study. *Frontiers in cardiovascular medicine*. 2021 Jun 28; 8:653405.
12. Werhahn SM, Becker C, Mende M, Haarmann H, Nolte K, Laufs U, Zeynalova S, Loeffler M, Dages N, Husser D, Doerr M. NT-proBNP as a marker for atrial fibrillation and heart failure in four observational outpatient trials. *ESC heart failure*. 2022 Feb;9(1):100-9.
13. Pathan F, D'Elia N, Nolan MT, Marwick TH, Negishi K. Normal ranges of left atrial strain by speckle-tracking echocardiography: a systematic review and meta-analysis. *Journal of the American Society of Echocardiography*. 2017 Jan 1;30(1):59-70.
14. Nielsen AB, Skaarup KG, Hauser R, Johansen ND, Lassen MC, Jensen GB, Schnohr P, Møgelvang R, Biering-Sørensen T. Normal values and reference ranges for left atrial strain by speckle-tracking echocardiography: the Copenhagen City Heart Study. *European Heart Journal-Cardiovascular Imaging*. 2022 Jan 1;23(1):42-51.
15. Kadappu KK, Boyd A, Eshoo S, Haluska B, Yeo AE, Marwick TH, Thomas L. Changes in left atrial volume in diabetes mellitus: more than diastolic dysfunction. *European Heart Journal-Cardiovascular Imaging*. 2012 Dec 1;13(12):1016-23.
16. Graça B, Ferreira MJ, Donato P, Gomes L, Castelo-Branco M, Caseiro-Alves F. Left atrial dysfunction in type 2 diabetes mellitus: insights from cardiac MRI. *European radiology*. 2014 Nov;24(11):2669-76.
17. Gulmez O, Demirağ N, Parildar H, Cigerli O. Assessment of left atrial function in patients with type 2 diabetes mellitus with a disease duration of six months. *South African Journal of Diabetes and Vascular Disease*. 2018 Jul 1;15(1):23-8.
18. Li X, Dong Y, Zheng C, Wang P, Xu M, Zou C, Wang L. Assessment of real-time three-dimensional echocardiography as a tool for evaluating left atrial volume and function in patients with type 2 diabetes mellitus. *Aging (Albany NY)*. 2020 Dec 3;13(1):991.
19. Dang HN, Luong TV, Tran TT. Evaluating left atrial function changes by speckle tracking echocardiography in type 2 diabetes patients in Central Vietnam: a cross-sectional comparative study. *The Egyptian Heart Journal*. 2024 Mar 28;76(1):38.
20. Wang S, Cui C, Li Y, Zhang R, Zhao Q, Liu R, Huang D, Liu L. Interaction effect of type 2 diabetes mellitus and hypertension on left atrial function: a three-dimensional echocardiography study. *Quantitative Imaging in Medicine and Surgery*. 2023 Sep 21;13(12):8107.
21. Nabati M, Moradgholi F, Moosazadeh M, Parsaee H. The correlation between epicardial fat thickness and longitudinal left atrial reservoir strain in patients with type 2 diabetes mellitus and controls. *The ultrasound journal*. 2023 Sep 12;15(1):37.
22. Gupta DK, Shah AM, Giugliano RP, Ruff CT, Antman EM, Grip LT, Deenadayalu N, Hoffman E, Patel I, Shi M, Mercuri M. Left atrial structure and function in atrial fibrillation: ENGAGE AF-TIMI 48. *European heart journal*. 2014 Jun 7;35(22):1457-65.
23. Hijazi Z, Wallentin L, Siegbahn A, Andersson U, Christersson C, Ezekowitz J, Gersh BJ, Hanna M, Hohnloser S, Horowitz J, Huber K. N-terminal pro-B-type natriuretic peptide for risk assessment in patients with atrial fibrillation: insights from the ARISTOTLE trial (Apixaban for the prevention of stroke in subjects with atrial fibrillation). *Journal of the American College of Cardiology*. 2013 Jun 4;61(22):2274-84.
24. Santema BT, Chan MM, Tromp J, Dokter M, van Der Wal HH, Emmens JE, Takens J, Samani NJ, Ng LL, Lang CC, van Der Meer P. The influence of atrial fibrillation on the levels of NT-proBNP versus GDF-15 in patients with heart failure. *Clinical Research in Cardiology*. 2020 Mar;109(3):331-8.
25. Coppens M, Eikelboom JW, Hart RG, Yusuf S, Lip GY, Dorian P, Shestakovska O, Connolly SJ. The CHA2DS2-VASc score identifies those patients with atrial fibrillation and a CHADS2 score of 1 who are unlikely to benefit from oral anticoagulant therapy. *European heart journal*. 2013 Jan 14;34(3):170-6.
26. Tiwari S, Løchen ML, Jacobsen BK, Hopstock LA, Nyrnes A, Njølstad I, Mathiesen EB, Schirmer H. CHA2DS2-VASc score, left atrial size and atrial fibrillation as stroke risk factors in the Tromsø Study. *Open Heart*. 2016 Sep 6;3(2).