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ORIGINAL RESEARCH

Association of Diabetes Mellitus with Carotid Artery Stenosis Undergoing Coronary Artery Bypass Graft in Bangladesh: A Prospective Cross-Sectional Study

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Background: Atherosclerosis is a systemic vascular disease commonly affecting coronary and carotid arteries, particularly in diabetes mellitus (DM). This study assessed the association of DM with significant carotid artery stenosis (CAS) among the coronary artery disease (CAD) population undergoing isolated elective coronary artery bypass graft (CABG) surgery.

Methods: A prospective cross-sectional study evaluated 100 Bangladeshi CAD patients who underwent isolated elective CABG from January 2017 to September 2019. Initially, a univariate analysis curtails the risk patterns, followed by a Pearson correlation analysis of significant CAS and glycated haemoglobin (HbA1c).

Results: Although the majority of patients were male, females were higher in the diabetic than non-diabetic group (38.1% vs 15.5%; p=0.01). Overall, ~38% of diabetic patients had significantly higher ≥50% CAS. Further, 28.6% and 9.5% of the diabetic sample had 50–70% and >70% CAS, respectively, which is significantly (p =0.02) higher than the non-diabetic sample (8.6% and 1.7%, respectively). Additionally, diabetes was significantly more associated with both unilateral (31.0% vs 22.4%) and bilateral (45.2% vs 22.4%) CAS than the non-diabetic population (p=0.006). The Pearson correlation coefficient shows a significant positive association between higher glycated haemoglobin levels and >50% CAS (correlation coefficient 0.270; p = 0.007).

Conclusion: We found higher HbA1c had a significant positive correlation with >50% CAS in diabetic patients undergoing elective CABG, recommending preoperative carotid screening, especially elderly individuals.

Keywords: carotid artery stenosis, coronary artery disease, diabetes mellitus, duplex scan

Introduction

Cardiovascular disease (CVD), ranging from coronary artery disease (CAD) to cerebrovascular and peripheral arterial diseases (PAD), remains one of the major causes of morbidity and mortality worldwide, such that even as infectious diseases continue to decline in importance CVD is likely to continue to have a major impact.[1] Because of its systemic nature, atherosclerosis also involves the carotid arteries in patients with CAD. Coronary atherosclerosis is more commonly associated with myocardial infarction (MI) and angina and its involvement of cerebral arteries results stroke and transient ischemic attack (TIA).[2] With as many as 118 million cases globally by the year 2035,[3] diabetes mellitus (DM) has become a largest public health issue worldwide.[4] It is even alarming to be noted that the prevalence of DM in Bangladesh has increased considerably, and as per projection it might reach to 13% by 2030.[4] DM presents one of the most important risk factors for incidence and prevalence of CV morbidity and mortality, increasing the risk of coronary

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(CAD), cerebrovascular disease (CD) and peripheral arterial diseases (PAD) several fold, particularly in women that present traditionally lower cardiovascular risk.[5–7]

In patients with diabetes, atherosclerosis preferentially affects the carotid bifurcation and proximal internal carotid artery,[8] prevalence of CAS in CAD patients varies from 30% to 70%. It is noteworthy that a high proportion of patients scheduled for coronary artery bypass grafting (CABG) have demonstrated severe carotid artery stenosis.[9–11] Existing literature found significant carotid stenosis, ~2% incidence, and ~25% mortality events are often implicated as a cause of post-CABG stroke, which is why surgeons require preoperative carotid screening to optimise postoperative outcomes.[11] Carotid Artery Duplex Scan (CADS) is noninvasive and readily available, but it is an excellent diagnostic tool for assessing the severity of CAS in routine carotid screening and is helpful in risk stratification and treatment planning.[10–12] Carotid scans can help prevent postoperative neurological events by accurately identifying high-risk patients, potentially leading to reduced mortality, shorter hospital stays, and healthcare cost savings.[13]

This study observed the prevalence and association of CAS in diabetic patients undergoing isolated CABG surgery compared to the non-diabetic population, emphasizing the importance of preoperative carotid screening for early optimization.

Materials and Methods

Study Design and Population

The study was a comparative cross-sectional survey carried out at the Department of Cardiac Surgery, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh, from July 2017 to August 2019. The study population was identified as cases admitted under Department for elective Coronary Artery Bypass Grafting (CABG) and the sampling unit considered was each CABG case. Patients meeting selection criteria were purposefully sampled until 100 participants were reached. Participants were divided into two groups: A group (with diabetes and CABG) and B group (without diabetes; underwent to the same procedure, identified by American Diabetes Association criteria). Ethical clearance was obtained from relevant committees and institutional review boards (Ref: BSMMU/2018/8106). After explaining the study's nature and purpose, informed written consent was obtained from all participants, and the study complied with the Declaration of Helsinki.

Data Collection Procedure

All patients admitted for an elective CABG and consenting to participate in the study, if otherwise eligible for inclusion in the analysis, were included. Eligibility criteria included patients with CAD who were scheduled for CABG. Exclusion Criteria included patients with concomitant or previous definite stroke and those with a history of carotid artery endarterectomy within 6 months before CABG were excluded as well as hemodynamically unstable cases, emergency CABG patients and combined procedures with the above mentioned. The clinical history, physical examination and results of investigations were detailed in this section for each subject. We performed in silico assessment after categorizing the patients into diabetic and non-diabetic groups to evaluate CADS performance. Describers like sociodemographics and preoperative parameters semi-structured questionnaires were used to capture both the sociodemographic characteristics as well as preoperative parameters that were further supplemented in a checklist which recorded various variables from patients' admission records and investigation reports. Data acquisition procedures comprised interviews, face-to-face interview techniques, and history sheet and report abstracting. After the interviews but prior to processing, quality-control checks were conducted to ensure completion and internal-consistency. The data were then cleaned, sorted, and coded in preparation for analysis and the data was encrypted.

Operational Definitions

Diabetes

The diagnostic criteria include either one finding of the following:[14] Fasting plasma glucose >126 mg/dl (7.0 mmol/l) after at least 8 hours of fasting or 2-hour plasma glucose >200 mg/dl (11.1 mmol/l) during an oral glucose tolerance

test using a 75-gram glucose load; or Haemoglobin A1c >6.5% (48 mmol/mol) or random plasma glucose >200 mg/dl (11.1 mmol/l) in a patient exhibiting classic symptoms of hyperglycemia or hyperglycemic crisis.

Coronary Artery Disease (CAD)

Coronary artery disease (CAD) as a lumen diameter stenosis of >50% in at least one major coronary artery.[9] The extent of CAD was categorized as follows: Single vessel disease (SVD), Double vessel disease (DVD), Triple vessel disease (TVD), and Left main stem disease.

Carotid Artery Stenosis (CAS)

Grant and colleagues[15] proposed a stratification system for carotid artery stenosis based on gray-scale and Doppler ultrasound findings. This system categorizes stenosis into six strata: normal (no stenosis), <50% stenosis, 50%–69% stenosis, >70% stenosis but less than near occlusion, near occlusion, and total occlusion.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 28.0 software. Unpaired Student's *t*-test was utilised to compare continuous variables, while Chi-square and Fisher's exact tests (if sample size <5) were employed for categorical variables as appropriate. Data quality was assessed using the Shapiro–Wilk test and multicollinearity tests to evaluate normality and skewness. Pearson correlation coefficient was applied to evaluate the association between carotid artery stenosis (CAS) and diabetes mellitus (DM). A p-value of <0.05 was considered statistically significant.

Result

We found similar age (Mean ± SD) differences between the diabetic and non-diabetic study populations (57.4 ± 8.06 vs 56.2 ± 9.07 years) (Table 1). Although most patients were male, females were higher in the diabetic group (38.1% vs 15.5%; p = 0.01). Furthermore, Mean BMI was insignificant (25.2 ±2.1 vs 24.7 ±1.3 kg/m², p = 0.12) between study groups. Further, carotid bruit was found significantly more in the diabetic population than in the non-diabetic group (31% vs 6.9%; p = 0.04). Table 1 reports the demographic information of study participants. Table S1 presents significant variations between the two groups in terms of fasting blood sugar, 2-hour postprandial blood glucose levels, and HbA1c

Table 1 Basic Characteristics of Study Participants (N=100)

		Study Population (N=100)		p value
		Diabetes (n=42) f (%)	Non-Diabetes (n=58) f (%)	
Age (Mean ±SD) years		57.4 ± 8.06	56.2 ± 9.07	0.49
Gender	Male	26 (61.9)	49 (84.5)	0.01
	Female	16 (38.1)	9 (15.5)	
BMI (Mean ±SD) kg/m^2		25.25 ± 2.10	24.72 ± 1.34	0.12
Chest pain		39 (92.9)	58 (100)	0.03
Palpitation		31 (73.8)	38 (65.5)	0.37
Dyspnea		9 (21.4)	13 (22.4)	0.90
Syncope		5 (11.9)	2(3.4)	0.10
Carotid bruit		13 (31)	4(6.9)	0.002
Smoking		30 (71.4)	49 (75.9)	0.61

(*Continued*)

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Table 1 (Continued).

	Study Population (N=100)		p value
	Diabetes (n=42) f (%)	Non-Diabetes (n=58) f (%)	
Family history			
DM	28 (66.7)	30 (51.7)	0.13
IHD	13 (31)	28 (48.3)	0.01
Stroke	8 (19)	12 (20.7)	0.83
Co-existing medical illness			
HTN	39 (92.9)	53 (91.4)	0.78
Dyslipidemia	40 (95.2)	55 (94.8)	0.92
PVD	3 (7.1)	1 (1.7)	0.17
TIA	7 (16.7)	5 (8.6)	0.22
Drug history			
Anti-hypertensive	39 (92.9)	54 (93.1)	0.96
Lipid lowering	40 (95.2)	55 (94.8)	0.92
Oral hypoglycemic	41 (97.6)	0 (0)	<0.001
Insulin	25 (59.5)	0(0)	<0.001

Notes: Student's *t*-test, Chi-square test (χ^2) and Fisher's exact test (if sample size <5) were used to measure the level of significance, as appropriate. A p value of <0.05 was considered to be significant.
Abbreviations: N, total number of population; n, number of observations in each group; f, Frequency; DM, Diabetes mellitus; IHD, Ischemic Heart Disease; HTN, Hypertension; PVD, Peripheral Vascular Disease; TIA, Transient Ischemic Attack.

($p < 0.001$). Although TVD was lower among people with diabetes than in the non-diabetic sample (66.7% vs 81%), LM disease was higher in the diabetic sample (19% vs 5.2%) (Table S2).

The overall significant ≥50% carotid stenosis was higher with diabetes than in the non-diabetic sample (38.1% vs 10.3%, $p = 0.001$). Further, 28.6% and 9.5% of the diabetic sample had 50–70% and >70% CAS, respectively, which is significantly ($p = 0.02$) higher than the non-diabetic sample (8.6% and 1.7%, respectively) (Table 2). We also found that

Table 2 Characteristics and Distribution of Carotid Artery Disease by Study Groups

Characteristics and Distribution of CAS	Study Population (N=100)		p value
	Diabetes (n=42) f (%)	Non-Diabetes (n=58) f (%)	
Percentage of stenosis			
Normal	10 (23.8)	32 (55.2)	0.02
<50% stenosis	16 (38.1)	20 (34.5)	
50%–70% stenosis	12 (28.6)	5 (8.6)	
>70% stenosis	4 (9.5)	1 (1.7)	
Overall ≥50% stenosis	16 (38.1)	6 (10.3)	0.001

(*Continued*)

Table 2 (Continued).

Characteristics and Distribution of CAS	Study Population (N=100)		p value
	Diabetes (n=42) f (%)	Non-Diabetes (n=58) f (%)	
Site of the CAS			
Carotid bulb	19 (45.2)	13 (22.4)	0.01
RCCA	22 (52.4)	14 (24.1)	0.004
RICA	19 (45.2)	8 (13.8)	0.001
LCCA	16 (38.1)	16 (27.6)	0.26
LICA	12 (28.6)	7 (12.1)	0.03
Laterality of CAS			
Unilateral	13 (31.0)	13 (22.4)	0.006
Bilateral	19 (45.2)	13 (22.4)	

Notes: Chi-square test (χ^2) was used to measure the level of significance. P <0.05 was considered to be significant.
Abbreviations: RCCA, Right Common Carotid Artery; RICA, Right Internal Carotid Artery; LCCA, Left Common Carotid Artery; LICA, Left Internal Carotid Artery.

Table 3 Correlation Between Preoperative HbA1c and Significant (≥50%) Carotid Artery Stenosis

		HbA1c	Significant CAS
HbA1c	Pearson Correlation	1	0.270
	p value		0.007
	N	100	100
Significant CAS	Pearson Correlation	0.270	1
	p value	0.007	
	N	100	100

Notes: N, Total number of patients; Correlation is significant at the 0.01 level.

the diabetic population had a higher CAS occurrence at the carotid bulb (p = 0.01), right common carotid artery (p = 0.004), and right internal carotid artery (p = 0.001) and left internal carotid artery (p = 0.03) compared to the non-diabetic population. Additionally, unilateral CAS (31.0% vs 22.4%) and bilateral CAS (45.2% vs 22.4%) were significantly more among diabetics than non-diabetics population (p = 0.006).

The Pearson correlation coefficient test indicates a significant positive association between the higher glycated hemoglobin level and significant CAS (>50% stenosis), with a correlation coefficient of 0.270 and a p-value of 0.007 (Table 3). The datasets were normally distributed, and no significant collinearity was observed among independent variables.

Discussion

We found that carotid artery stenosis was nearly 2-fold common among diabetic than non-diabetic patients undergoing CABG surgery. Furthermore, >50% CAS was about three times higher in the CABG population with diabetes.

We found significantly higher CAS in the diabetic than the non-diabetic population, supported by existing findings where authors found the prevalence of concomitant CAS in CAD is approximately 50%-70%.[10–12]

Further, existing literature discovered that patients with significant CAS and CAD who are scheduled for coronary artery bypass graft (CABG) surgery are at increased risk of postoperative stroke.[9,12] Additionally, Wanamaker and colleagues[16] also highlight the higher susceptibility of bilateral CAS in patients with DM, similar to our study findings. Although DM is an established risk factor for atherosclerotic cardiovascular disease, this is the first Bangladeshi study demonstrating a significant positive correlation between significant CAS and CAD undergoing CABG among the DM population.

The age distribution was similar in both groups, with the 50–59 age range being the most prevalent for diabetic and non-diabetic individuals, supporting previous study findings.[10] However, we also found a higher prevalence of significant CAS in females, with CAD undergoing CABG surgery from the diabetic group compared to those without diabetes, similar to existing study findings.[9] Similar to our study findings, a recent study by Noh and colleagues[17] found that HbA1c significantly correlated with significant CAS, supporting existing study findings.[18] Although our study was not aimed at evaluating the pathophysiology of CAS among CAD with DM patients, chronic hyperglycemia in uncontrolled DM leads to endothelial dysfunction, increasing oxidative stress and promoting inflammation within the arterial walls characterized by the accumulation of lipids, inflammatory cells, and fibrous tissue in the carotid arteries, leading to narrowing of the carotid arteries.[19,20]

Like any study, we need to acknowledge a few limitations. The study's scope was confined to a small patient cohort over a limited timeframe. Although we evaluated the study population from a super-specialised tertiary referral hospital, which might not represent the overall scenarios across Bangladesh as well as worldwide. Furthermore, the assessment did not evaluate inter-observer variability in carotid duplex scanning. Additionally, as a cross-sectional study, clinical endpoints were not longitudinally monitored. Finally, a higher prevalence of CAD in women associated with DM than non-diabetic remains speculative and needs to be confirmed with further studies; plausibly, a genetic analysis might shed light on the robustness of the findings.

Conclusion

We found a high prevalence of carotid artery stenosis in diabetic patients undergoing elective CABG, highlighting the importance of preoperative carotid screening for early detection and preoperative optimisation, especially for individuals aged ≥50 years.

Data Sharing Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions. Dr. Md. Abir Tazim Chowdhury had full access to all of the data in this study and took complete responsibility for the integrity of the data and the accuracy of the data analysis.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declare no conflicts of interest in this work.

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