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Association of SYNTAX score, ankle-brachial index, and toe-brachial index with peripheral arterial disease following CABG

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Abstract

BACKGROUND: Peripheral arterial disease (PAD) is a common comorbidity in patients undergoing coronary artery bypass grafting (CABG) and is associated with increased morbidity. Early identification of PAD in this population is clinically important; however, the relationship between coronary disease complexity and peripheral arterial involvement remains unclear.

This study aimed to evaluate the association of the SYNTAX score, ankle–brachial index (ABI), and toe–brachial index (TBI) with the development of peripheral arterial disease following CABG.

METHODS: In this retrospective study, 87 patients who underwent CABG were evaluated four years after surgery for the presence of PAD. Baseline SYNTAX score, ABI, and TBI were measured prior to CABG. PAD was diagnosed based on clinical symptoms in combination with abnormal ABI and/or TBI findings and was confirmed by Doppler ultrasonography when indicated. Associations between SYNTAX score, ABI, TBI, and PAD were analyzed using appropriate statistical tests.

RESULTS: During the follow-up period, 7 patients (8.0%) developed PAD. Diabetes mellitus was significantly more prevalent among patients with PAD compared to those without PAD (85.7% vs. 45.0%, P = 0.039). Right ABI (P = 0.005), left TBI (P = 0.008), and right TBI (P = 0.010) were significantly associated with PAD, whereas left ABI was not. Although the SYNTAX score was not directly associated with PAD incidence, higher SYNTAX scores were significantly correlated with greater reductions in both left ABI (r = -0.296, P = 0.005) and right ABI (r = -0.220, P = 0.040) 4 years after CABG.

CONCLUSION: Peripheral arterial disease following CABG was significantly associated with diabetes mellitus and with lower ABI and TBI values, particularly in the right lower extremity. While the SYNTAX score was not directly associated with PAD occurrence, it was correlated with longitudinal declines in ABI, suggesting an association between coronary disease complexity and systemic vascular dysfunction.

Keywords: Peripheral Artery Disease; Coronary Artery Bypass Surgery; Coronary SYNTAX Score; Ankle Brachial Index; Toe Brachial Index

Introduction

Peripheral arterial disease (PAD)[1], a condition characterized by the narrowing or blockage of arteries in the legs, is a significant complication following coronary artery bypass grafting (CABG)[1], often leading to substantial morbidity and mortality. Early detection of PAD is crucial for optimizing patient outcomes, but traditional risk factors frequently fail to predict PAD development in this population accurately[2,3]. This condition can lead to reduced blood flow, pain, and even limb ischemia. Identifying patients at high risk for PAD is crucial for early detection, timely intervention, and improved outcomes. Previous studies have established a strong association between diabetes and PAD following CABG[4]. However, the role of other factors, such as the complexity of coronary artery disease, in predicting PAD risk remains an area of active investigation. The SYNTAX score, a widely used tool to quantify the complexity of coronary artery disease based on the extent and severity of lesions, has been shown to correlate with increased cardiovascular risk[5–7]. This study aimed to investigate the relationship between the SYNTAX score and the development of PAD following CABG. It was hypothesized that patients with higher SYNTAX scores, indicative of more complex coronary artery disease, would be at increased risk for PAD due to the systemic nature of atherosclerosis. Additionally, we explored the role of ankle-brachial index (ABI) and toe-brachial index (TBI) as predictors of PAD development. ABI and TBI are non-invasive tests used to measure blood flow to the legs. By understanding the factors that contribute to PAD risk following CABG, we can develop more targeted preventive strategies and improve patient outcomes. This study provides valuable insights into the association of the SYNTAX score, ABI, and TBI with PAD risk, potentially leading to improved risk stratification and personalized management for patients undergoing CABG.

Method

Study Design and Population

This retrospective observational study included 87 consecutive patients who underwent coronary artery bypass grafting (CABG) and were evaluated 4 years after surgery. Eligible participants were aged ≥18 years and had complete coronary angiographic data available for SYNTAX score calculation. Patients with documented peripheral arterial disease prior to CABG, history of major lower extremity vascular surgery, or severe diabetic microvascular or macrovascular complications that could interfere with PAD assessment were excluded. Both diabetic and non-diabetic patients were included in the study.

The study protocol was approved by the Ethics Committee of Iran University of Medical Sciences (Approval No. IR.IUMS.FMD.REC.1402.139), and written informed consent was obtained from all participants.

Data Collection and Measurements

Baseline demographic characteristics and clinical data, including cardiovascular risk factors, were obtained from electronic medical records. Coronary angiographic findings were reviewed, and the SYNTAX score was calculated according to standard methodology to quantify the complexity of coronary artery disease.

Ankle-brachial index (ABI) and toe-brachial index (TBI) were measured prior to CABG using standard non-invasive techniques. ABI was calculated as the ratio of systolic blood pressure measured at the ankle to that measured at the brachial artery, while TBI was calculated as the ratio of toe systolic pressure to brachial systolic pressure. ABI values were categorized as <0.85 (suggestive of PAD), 0.85–1.50 (normal), and >1.50 (incompressible arteries).

Given the known limitations of ABI in patients with diabetes due to medial arterial calcification, TBI was included as a complementary and more reliable indicator of peripheral arterial perfusion in this population.

Assessment of Peripheral Arterial Disease

Peripheral arterial disease was assessed 4 years after CABG. PAD diagnosis was based on the presence of intermittent claudication symptoms

combined with abnormal ABI and/or TBI values. Doppler ultrasonography was used to confirm PAD when clinically indicated, and peripheral vascular angiography was performed in selected cases when further diagnostic clarification was required.

Statistical Analysis

Continuous variables with normal distribution were reported as mean ± standard deviation and compared between patients with and without PAD using the independent t-test. Non-normally distributed continuous variables were analyzed using the Mann–Whitney U test. Categorical variables, including diabetes mellitus, hypertension, dyslipidemia, and smoking status, were compared using the chi-square test or Fisher's exact test, as appropriate. Correlations between SYNTAX score and ABI or TBI values were assessed using Spearman's correlation analysis. A two-sided P value < 0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA).

Results

A total of 87 patients who underwent coronary artery bypass grafting (CABG) were consecutively enrolled in this study. Peripheral artery disease (PAD) was assessed 4 years after surgery based on clinical symptoms and objective vascular evaluations. The mean age of the study population was 60.4 ± 8.5 years, and 66 patients (75.9%) were male. During the 4-year follow-up period, 7 patients (8.0%) developed PAD accompanied by intermittent claudication. Patients were classified as having PAD based on the presence of intermittent claudication symptoms in combination with abnormal ankle-brachial index (ABI) and/or toe-brachial index (TBI) findings, which were confirmed by Doppler ultrasonography. When patients with PAD were compared to those without PAD, no statistically significant differences were observed regarding sex, age, history of hypertension, dyslipidemia, smoking status, family history of cardiovascular disease, urgent CABG, chronic obstructive pulmonary disease, renal failure, or cerebrovascular accident. However, the prevalence of diabetes mellitus was significantly higher among patients who developed PAD after CABG (85.7% vs. 45.0%, P = 0.039). These findings are summarized in Table 1.

While no significant correlation was observed between age, SYNTAX score, and Left ABI, a notable association emerged between baseline left TBI, baseline right TBI, and baseline right ABI and the development of peripheral arterial disease during the four-year follow-up period, as illustrated in Table 2.

The present study did not identify a significant association between clinically overt peripheral arterial disease and Left ABI. However, Right ABI demonstrated a significant association with the severity of clinical PAD according to the predefined ABI categories (Table 3).

A significant inverse correlation was observed between SYNTAX score and both left and right ankle–brachial index (ABI) values four years after CABG, as assessed using Spearman's correlation analysis. In contrast, no significant correlation was found between SYNTAX score and left or right toe–brachial index (TBI). These findings are summarized in Table 4.

As depicted in Figure 1, no significant association was observed between SYNTAX score and the incidence of clinically overt peripheral artery disease after CABG.

Discussion

The present study investigated 87 patients who underwent CABG, of whom 7 developed PAD with intermittent claudication over a 4-year follow-up period. Diabetes mellitus was found to be significantly associated with the development of PAD after CABG. Diabetes mellitus was not considered an exclusion criterion in the present study, and both diabetic and non-diabetic patients were included to allow assessment of its association with peripheral arterial disease. While no significant associations were observed between age, SYNTAX score, or left ABI and PAD, significant correlations were found between baseline right ABI, left TBI, and right TBI and

Table 1. Relationship between clinical PAD and patients' past medical disease in CABG patients

Variable	Without PAD (n = 80)	With PAD (n = 7)	P-value
Male sex, n (%)	60 (75.0)	6 (85.7)	0.520
Age (years), mean ± SD	60.7 ± 8.2	58.1 ± 12.7	0.450
Diabetes mellitus, n (%)	36 (45.0)	6 (85.7)	**0.039**
History of hypertension, n (%)	50 (62.5)	3 (42.9)	0.300
Dyslipidemia, n (%)	37 (46.3)	4 (57.1)	0.580
Smoking history, n (%)	15 (18.8)	1 (14.3)	0.700
Family history of cardiovascular disease, n (%)	27 (33.8)	1 (14.3)	1.000
Urgent CABG, n (%)	2 (2.5)	0 (0.0)	0.670
Chronic obstructive pulmonary disease, n (%)	3 (3.8)	0 (0.0)	0.600
Renal failure, n (%)	7 (8.8)	1 (14.3)	0.620
Cerebrovascular accident, n (%)	3 (3.8)	0 (0.0)	0.600

Abbreviations:PAD, peripheral artery disease; CABG, coronary artery bypass grafting; SD, standard deviation.

Table 2. Relationship between PAD and SYNTAX.score, ABI, and TBI of CABG patients

Variable	Without PAD (n = 80)	With PAD (n = 7)	P-value
SYNTAX score, mean ± SD	24.47 ± 9.21	26.79 ± 9.54	0.520
Left ABI, mean ± SD	1.00 ± 0.26	0.87 ± 0.24	0.320
Right ABI, mean ± SD	0.96 ± 0.22	0.70 ± 0.26	0.005
Left TBI, mean ± SD	1.02 ± 0.24	0.73 ± 0.22	0.008
Right TBI, mean ± SD	1.03 ± 0.39	0.77 ± 0.23	0.010

Abbreviation:PAD: Peripheral artery disease, SD: Standard Deviation, ABI: Ankle Brachial index, TBI: Toe Brachial Index

Table 3. Relationship between ABI and clinical PAD in CABG patients

ABI category		Without PAD (n = 80)	With PAD (n = 7)	P-value
Left ABI	ABI < 0.85	20 (25.0)	3 (42.9)	
	0.85 ≤ ABI ≤ 1.50	58 (72.5)	4 (57.1)	0.550
	ABI > 1.50	2 (2.5)	0 (0.0)	
Right ABI	ABI < 0.85	22 (27.5)	6 (85.7)	
	0.85 ≤ ABI ≤ 1.50	56 (70.0)	1 (14.3)	**0.007**
	ABI > 1.50	2 (2.5)	0 (0.0)	

Table 4. Correlation between SYNTAX score and post-operative ankle–brachial index and toe–brachial index four years after CABG

Variable	Correlation coefficient (r)	P-value
Left ABI	-0.296	0.005
Right ABI	-0.220	0.040
Left TBI	-0.057	0.602
Right TBI	-0.153	0.158

Correlation analysis: Spearman's correlation
Abbreviations: ABI, ankle–brachial index; TBI, toe–brachial index; CABG, coronary artery bypass grafting.

the development of peripheral arterial disease during follow-up. In patients with diabetes, ABI measurements may be falsely normal or elevated due to medial arterial calcification, whereas TBI provides a more reliable assessment of peripheral perfusion. This may partly explain the stronger association observed between PAD and TBI compared to ABI in the present study. The influence of diabetes on ABI performance should be considered when interpreting results, emphasizing the need for comprehensive vascular assessment in this population. A higher SYNTAX score was correlated with greater reductions in ABI values 4 years post-CABG, particularly in the right leg, which showed a significant relationship with the severity of clinical PAD. Although no direct association between SYNTAX score and clinically overt PAD was identified, these findings suggest that complex coronary artery disease may contribute to systemic vascular dysfunction, manifesting as subclinical changes detectable by ABI. Surgical stress combined with underlying vascular disease may further exacerbate peripheral perfusion

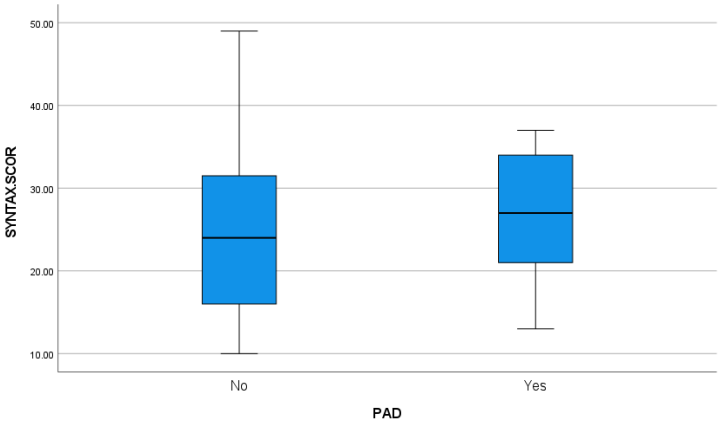

Figure 1. Relationship between SYNTAX score and PAD in CABG patients

deficits in these patients. Our findings align with a growing body of literature demonstrating the association between diabetes and PAD following CABG[8–10]. Previous studies have confirmed a significantly increased risk of PAD in diabetic patients undergoing CABG compared to non-diabetic patients[9,11,12]. Similarly, Bonacchi et al. reported that PAD patients undergoing CABG experienced higher rates of stroke (P = 0.04), acute kidney injury (P = 0.003), and limb ischemia requiring intervention (P < 0.001). However, overall mortality was not significantly different between PAD and non-PAD groups. Extended cardiopulmonary bypass and cross-clamp times, along with postoperative low cardiac output, were associated with increased early mortality in PAD patients[13]. Harnphadungkit et al. found that among 192 CABG candidates, 12.5% had PAD, but only 4.2% had a prior diagnosis; age was the only significant risk factor, and PAD patients had lower left ventricular ejection fraction (LVEF, P = 0.031). In a 10-year cohort study by Collison et al., CABG patients with peripheral vascular disease (PVD) experienced higher rates of cardiac, systemic, renal, neurologic, and pulmonary complications compared to those without PVD[14]. The observed higher incidence of PAD in the right leg is supported by previous studies, which indicate that while the right leg may show more pronounced post-exercise abnormalities, the left leg exhibits a higher resting prevalence. Functional assessments post-exercise may reveal different patterns of PAD severity, and anatomical variations in arterial supply, as well as hemodynamic differences, may contribute to this asymmetry[15]. The association between SYNTAX score and greater reductions in ABI is consistent with evidence suggesting that patients with more complex coronary artery disease are likely to have diffuse systemic atherosclerosis, including in the peripheral arteries[16,17]. Although a direct link between SYNTAX score and clinically overt PAD was not observed, longitudinal studies are warranted to explore whether progressive vascular dysfunction may increase PAD risk over time. In addition to diabetes and coronary disease complexity, other traditional cardiovascular risk factors, including hypertension, hyperlipidemia, smoking, and family history of cardiovascular disease, may contribute to the development of PAD following CABG[18]. Comprehensive risk assessment is essential for identifying patients at high risk and implementing preventive strategies. These findings have important clinical implications. Patients with diabetes should be considered at elevated risk for PAD and closely monitored using regular ABI and TBI assessments to identify early-stage disease and allow timely interventions. Further, patients with complex coronary artery disease, as indicated by high SYNTAX scores, may benefit from targeted strategies to optimize vascular health and mitigate PAD risk. Finally, several limitations of this study should be acknowledged. First, the relatively small number of patients who

developed clinically overt PAD (n = 7) limits the statistical power of subgroup analyses and may reduce the generalizability of the findings. Therefore, the results should be interpreted with caution, and the observed associations should be considered exploratory rather than definitive. Larger, prospective studies with higher PAD event rates are warranted to validate these findings and to further clarify the relationships between SYNTAX score, ABI, TBI, and PAD development following CABG.

Conclusion

These findings highlight the importance of comprehensive pre-operative risk assessment and post-operative surveillance for patients undergoing CABG, particularly those with diabetes. Regular monitoring for PAD, including ABI measurements, can facilitate early detection and intervention, potentially preventing the progression of the disease.

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Conflict of interests

The authors declare no conflict of interest.

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Author's Contributions

Study Conception or Design: JM; RH; EN
Data Acquisition: JM
Data Analysis or Interpretation: AGJ; PS; SMH
Manuscript Drafting: AE; EN
Critical Manuscript Revision: JM; AMN; SMH; ET; AD
All authors have approved the final manuscript and are responsible for all aspects of the work.

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