THE STUDY OF INVASIVE CORONARY ANGIOGRAPHIC PROFILE IN PATIENTS WITH ANGINA AND MYOCARDIAL BRIDGING

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ABSTRACT

Background: Myocardial bridging (MB) is a congenital coronary artery anomaly in which a segment of an epicardial coronary artery follows an intramyocardial course, resulting in dynamic systolic compression of the tunneled vessel. Although traditionally considered a benign anatomical variant, increasing evidence suggests that hemodynamically significant myocardial bridging may be associated with myocardial ischemia, angina, arrhythmias, and coronary atherosclerosis. Comprehensive evaluation of its clinical profile, angiographic characteristics, and relationship with coronary artery disease remains essential for appropriate diagnosis and management.

Aim and Objectives: To determine the prevalence, clinical profile, angiographic characteristics, and hemodynamic significance of myocardial bridging in patients undergoing coronary angiography at a tertiary care centre.

Objectives:

1. To study the prevalence and angiographic profile in patients with angina and myocardial bridging.
2. To study its association with atherosclerosis.

Materials and Methods: This prospective observational study was conducted in the Department of Cardiology at a tertiary care teaching hospital from January 2024 to June 2026. A total of 335 consecutive adult patients with angiographically confirmed myocardial bridging were included. Demographic characteristics, clinical presentation, cardiovascular risk factors, electrocardiographic and echocardiographic findings, angiographic characteristics, hemodynamic severity, Schwarz classification, and associated coronary artery disease were evaluated. Statistical analysis was performed using SPSS version 27.0, with a p-value <0.05 considered statistically significant.

Results: Among 335 patients, the majority belonged to the 50–59-year age group (23.0%), with a slight male predominance (54.6%). Typical angina was present in 50.1% of patients, while 49.9% had atypical chest pain or incidentally detected myocardial bridging. Hypertension (39.7%), dyslipidaemia (35.2%), and diabetes mellitus (33.4%) were the most common cardiovascular risk factors. Normal sinus rhythm was observed in 52.2% of patients, ST–T changes in 35.5%, troponin positivity in 22.7%, and regional wall motion abnormalities in 11.6%. Hemodynamic assessment showed that 80.0% of patients had less than 70% systolic compression, whereas 8.7% demonstrated persistent diastolic compression. Schwarz Type A myocardial bridging was identified in 77.3% of patients. The left anterior descending artery was involved in 99.7% of cases, predominantly affecting the mid-segment (77.3%), with a mean bridge length of 20.1 $\pm$6.8 mm. Concomitant coronary artery disease was present in 13.4% of patients, with proximal coronary involvement occurring more frequently than distal disease.

Conclusion: Myocardial bridging was predominantly a benign anatomical coronary anomaly characterized by mild-to-moderate hemodynamic involvement and limited association with obstructive coronary artery disease. The left anterior descending artery, particularly its mid-segment, was the principal site of involvement. Comprehensive invasive coronary angiographic evaluation, combined with hemodynamic assessment, is valuable for distinguishing incidental myocardial bridging from clinically significant disease, thereby facilitating accurate risk stratification and appropriate patient management.

Keywords: Myocardial bridging; Invasive coronary angiography; Left anterior descending artery; Angina; Hemodynamic significance; Schwarz classification; Coronary artery disease; Systolic compression; Coronary atherosclerosis; Myocardial ischemia.

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INTRODUCTION

Myocardial bridging (MB) is a congenital anatomical variant in which a segment of an epicardial coronary artery, most commonly the left anterior descending (LAD) artery, courses intramyocardially beneath a band of myocardial fibers instead of following its normal epicardial path (1,2). During ventricular systole, the tunneled coronary segment undergoes transient compression, producing the characteristic angiographic appearance known as the "milking effect (3)." Although myocardial bridging has traditionally been regarded as a benign congenital anomaly, growing evidence suggests that it may have important clinical implications in a subset of patients by contributing to myocardial ischemia, angina, acute coronary syndromes, ventricular arrhythmias, and, rarely, sudden cardiac death (4).

The clinical significance of myocardial bridging depends not only on its anatomical presence but also on the depth and length of the tunneled segment, the degree of systolic compression, persistence of luminal narrowing during diastole, heart rate, myocardial contractility, and the coexistence of coronary atherosclerosis (5,6). Since coronary blood flow to the left ventricle occurs predominantly during diastole, delayed relaxation of the bridged coronary segment may impair myocardial perfusion, particularly during tachycardia or increased myocardial oxygen demand. Consequently, while many individuals remain asymptomatic throughout life, others may experience exertional angina or ischemic cardiac events despite the absence of significant obstructive coronary artery disease (6,7).

The reported prevalence of myocardial bridging varies considerably according to the diagnostic modality used. Conventional invasive coronary angiography generally detects only functionally significant bridges and reports prevalence rates ranging from approximately 0.5% to 16%, whereas coronary computed tomography angiography and autopsy studies demonstrate substantially higher prevalence because they identify both superficial and deep myocardial bridges (8,9). Advances in coronary imaging techniques, including intravascular ultrasound, optical coherence tomography, fractional flow reserve, and coronary computed tomography angiography, have significantly improved the anatomical and physiological assessment of myocardial bridging, leading to better understanding of its clinical relevance (10,11).

Invasive coronary angiography remains the gold standard for identifying the dynamic systolic compression associated with myocardial bridging and allows simultaneous assessment of associated coronary artery disease. Angiographic evaluation provides detailed information regarding the location of the bridged segment, bridge length, severity of systolic narrowing, Schwarz classification, and the presence of concomitant proximal atherosclerotic disease (12). Such comprehensive evaluation is essential because the management and prognosis of myocardial bridging are influenced by both anatomical characteristics and hemodynamic significance rather than by the mere presence of a tunneled coronary artery (13).

Despite increasing recognition of myocardial bridging, data regarding its invasive angiographic profile, clinical presentation, and hemodynamic characteristics in the Indian population remain limited (14). Most available studies have focused primarily on prevalence, while detailed evaluation of angiographic morphology, Schwarz classification, hemodynamic severity, and associated coronary artery disease has been relatively scarce. A better understanding of these characteristics may help identify patients at increased risk of ischemic manifestations and guide appropriate therapeutic decision-making (15,16).

Therefore, the present study was undertaken to evaluate the invasive coronary angiographic profile of patients with myocardial bridging presenting with angina. The study aims to comprehensively assess the demographic characteristics, clinical presentation, cardiovascular risk factors, angiographic features, hemodynamic severity, Schwarz classification, and associated coronary

artery disease among patients with myocardial bridging undergoing invasive coronary angiography at a tertiary care centre. The findings are expected to provide valuable insights into the clinical and angiographic spectrum of myocardial bridging and contribute to improved diagnosis, risk stratification, and management of affected patients.

AIMS AND OBJECTIVES

Aim

To determine the prevalence, clinical profile, angiographic characteristics, and hemodynamic significance of myocardial bridging in patients undergoing coronary angiography at a tertiary care centre.

Objectives

1. To study the prevalence and angiographic profile in patients with angina and myocardial bridging.
2. To study its association with atherosclerosis.

MATERIALS AND METHODS

This hospital-based prospective observational study was conducted in the Department of Cardiology at a tertiary care teaching hospital from January 2024 to June 2026 after obtaining approval from the Institutional Ethics Committee. The study included 335 consecutive adult patients presenting with anginal symptoms who underwent invasive coronary angiography and were diagnosed with myocardial bridging. Patients fulfilling the inclusion criteria and providing informed written consent were enrolled consecutively. Baseline demographic characteristics, cardiovascular risk factors, clinical presentation, Canadian Cardiovascular Society (CCS) angina class, electrocardiographic findings, echocardiographic parameters, and relevant laboratory investigations were recorded using a predesigned structured clinical proforma.

All patients underwent conventional invasive coronary angiography using standard institutional protocols. Angiographic evaluation included identification of the involved coronary artery, segment of myocardial bridging, bridge length, severity of systolic compression, presence of the characteristic milking effect, hemodynamic severity, Schwarz classification, and the coexistence of coronary artery disease. Particular attention was given to assessing proximal and distal atherosclerotic involvement, as well as the extent of coronary vessel disease. Hemodynamic severity was categorized according to the degree of systolic and persistent diastolic compression to determine the functional significance of myocardial bridging.

All collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, while categorical variables were presented as frequencies and percentages. Appropriate descriptive and inferential statistical tests were applied for data analysis, and a p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1. Baseline Demographic Characteristics of Patients with Myocardial Bridging (N = 335)

Variable	Category	Number (n)	Percentage (%)
Age group (years)	30–39	44	13.1
	40–49	53	15.8
	50–59	77	23.0
	60–69	66	19.7
	70–79	57	17.0
	80–89	38	11.3
Sex	Male	183	54.6
	Female	152	45.4

In the present study, among the 335 patients with myocardial bridging, 44 (13.1%) patients belonged to the 30–39 years age group, 53 (15.8%) to the 40–49 years age group, 77 (23.0%) to the 50–59 years age group, 66 (19.7%) to the 60–69 years age group, 57 (17.0%) to the 70–79 years age group, and 38 (11.3%) to the 80–89 years age group. Regarding sex distribution, 183 (54.6%) patients were male and 152 (45.4%) were female.

Table 2. Clinical Presentation of Patients with Myocardial Bridging (N = 335)

Variable	Category	Number (n)	Percentage (%)
Symptom status	Typical angina / Symptomatic	168	50.1
	Atypical chest pain / Asymptomatic MB	167	49.9

CCS Angina Class	Class I	167	49.9
	Class II	107	31.9
	Class III	50	14.9
	Class IV	11	3.3
Dyspnea	Yes	97	29.0
	No	238	71.0
Palpitations	Yes	42	12.5
	No	293	87.5
Syncope	Yes	10	3.0
	No	325	97.0

In the present study, among the 335 patients with myocardial bridging, 168 (50.1%) patients had typical angina or were symptomatic, while 167 (49.9%) had atypical chest pain or asymptomatic myocardial bridging. According to the Canadian Cardiovascular Society (CCS) angina classification, 167 (49.9%) patients were classified as Class I, 107 (31.9%) as Class II, 50 (14.9%) as Class III, and 11 (3.3%) as Class IV. Dyspnea was present in 97 (29.0%) patients and absent in 238 (71.0%) patients. Palpitations were present in 42 (12.5%) patients and absent in 293 (87.5%) patients. Syncope was present in 10 (3.0%) patients and absent in 325 (97.0%) patients.

Table 3. Cardiovascular Risk Factors and Associated Cardiac Conditions Among Patients with Myocardial Bridging (N = 335)

Variable	Number (n)	Percentage (%)
Hypertension	133	39.7
Dyslipidemia	118	35.2
Diabetes mellitus	112	33.4
Tobacco/Smoking	98	29.3
Hypertrophic cardiomyopathy	4	1.2

In the present study, among the 335 patients with myocardial bridging, hypertension was present in 133 (39.7%) patients, dyslipidemia in 118 (35.2%) patients, diabetes mellitus in 112 (33.4%) patients, and tobacco use/smoking in 98 (29.3%) patients. Hypertrophic cardiomyopathy was observed in 4 (1.2%) patients.

Table 4. Laboratory and Electrocardiographic Findings (N = 335)

Variable	Category	Number (n)	Percentage (%)
Troponin	Positive	76	22.7
	Negative	259	77.3
ECG Findings	Normal sinus rhythm	175	52.2
	ST–T changes	119	35.5
	AWMI	24	7.2
	IWMI	16	4.8
	RBBB	1	0.3

In the present study, among the 335 patients with myocardial bridging, troponin was positive in 76 (22.7%) patients and negative in 259 (77.3%) patients. Electrocardiographic findings showed normal sinus rhythm in 175 (52.2%) patients, ST–T changes in 119 (35.5%) patients, anterior wall myocardial infarction (AWMI) in 24 (7.2%) patients, inferior wall myocardial infarction (IWMI) in 16 (4.8%) patients, and right bundle branch block (RBBB) in 1 (0.3%) patient.

Table 5. Echocardiographic Findings (N = 335)

Variable	Category	Number (n)	Percentage (%)
Regional wall motion abnormality	Present	39	11.6
	Absent	296	88.4

In the present study, among the 335 patients with myocardial bridging, regional wall motion abnormality was present in 39 (11.6%) patients and absent in 296 (88.4%) patients.

Table 6. Hemodynamic Severity and Schwarz Classification of Myocardial Bridging (N = 335)

Variable	Category	Number (n)	Percentage (%)
Hemodynamic Severity	<70% systolic compression	268	80.0
	>70% systolic compression only	38	11.3
	>70% systolic + persistent diastolic compression	29	8.7
Schwarz Classification	Type A	259	77.3
	Type B	43	12.8
	Type C	33	9.9

In the present study, among the 335 patients with myocardial bridging, 268 (80.0%) patients had less than 70% systolic compression, 38 (11.3%) had greater than 70% systolic compression only, and 29 (8.7%) had greater than 70% systolic compression with persistent diastolic compression. According to the Schwarz classification, 259 (77.3%) patients were classified as Type A, 43 (12.8%) as Type B, and 33 (9.9%) as Type C.

Table 7. Angiographic Characteristics of Myocardial Bridging (N = 335)

Variable	Category	Value
Mean bridge length (mm)	Mean ± SD	**20.1 ± 6.8**
Coronary artery involved	LAD	334 (99.7%)
	LCX	1 (0.3%)
	RCA	0 (0.0%)
Anatomical location	Mid segment	259 (77.3%)
	Distal segment	47 (14.0%)
	Proximal segment	29 (8.7%)

In the present study, the mean myocardial bridge length was 20.1 ± 6.8 mm. The left anterior descending (LAD) artery was involved in 334 (99.7%) patients, the left circumflex (LCX) artery in 1 (0.3%) patient, and no patient (0.0%) had involvement of the right coronary artery (RCA). Regarding the anatomical location of myocardial bridging, the mid segment was involved in 259 (77.3%) patients, the distal segment in 47 (14.0%) patients, and the proximal segment in 29 (8.7%) patients.

Table 8. Coronary Artery Disease Profile Among Patients with Myocardial Bridging (N = 335)

Variable	Category	Number (n)	Percentage (%)
Coronary artery disease	Present	45	13.4
	Absent	290	86.6
Distribution of CAD	Proximal to bridge	31	9.3
	Distal to bridge	14	4.2
Extent of CAD	Single-vessel disease	33	9.9
	Double-vessel disease	9	2.7
	Triple-vessel disease	3	0.9

In the present study, among the 335 patients with myocardial bridging, coronary artery disease was present in 45 (13.4%) patients and absent in 290 (86.6%) patients. Among patients with coronary artery disease, 31 (9.3%) had coronary artery disease proximal to the myocardial bridge, while 14 (4.2%) had coronary artery disease distal to the myocardial bridge. Regarding the extent of coronary artery disease, 33 (9.9%) patients had single-vessel disease, 9 (2.7%) had double-vessel disease, and 3 (0.9%) had triple-vessel disease.

DISCUSSION

The present study evaluated the invasive coronary angiographic profile of myocardial bridging (MB) in 335 patients undergoing coronary angiography and demonstrated that MB was predominantly identified in middle-aged and elderly individuals with a slight male predominance. The highest proportion of patients belonged to the 50–59-year age group (23.0%), while males constituted 54.6% of the study population. These findings are consistent with the observations of Molenkamp et al. (2002), who reported that clinically significant myocardial bridging is most commonly detected during the fifth and sixth decades of life, and Corban et al. (2014), who emphasized that although MB is congenital, symptomatic presentation usually occurs later in life because of age-related physiological and cardiovascular changes (17,18).

Typical angina was present in 50.1% of patients, whereas 49.9% had atypical chest pain or incidentally detected myocardial bridging. Most patients belonged to CCS Class I (49.9%) or Class II (31.9%), indicating mild-to-moderate limitation of physical activity. These findings support the observations of Schwarz et al. (1996), who reported that most patients with myocardial bridging have mild symptoms and respond well to conservative medical management (19). Similarly, Corban et al. (2014) concluded that symptom severity is more closely related to the physiological significance of myocardial bridging than to its anatomical presence alone (18).

Among the cardiovascular risk factors, hypertension (39.7%) was the most common, followed by dyslipidemia (35.2%), diabetes mellitus (33.4%), and tobacco use (29.3%). These risk factors may contribute to endothelial dysfunction and increased myocardial oxygen demand, thereby accentuating ischemic manifestations in susceptible individuals. Möhlenkamp et al. (2002) and Tarantini et al. (2016) similarly reported that conventional cardiovascular risk factors influence the clinical presentation of myocardial bridging without contributing to its congenital development (17,20).

Normal sinus rhythm was observed in 52.2% of patients, while ST–T changes were identified in 35.5%. Troponin positivity was present in 22.7%, and regional wall motion abnormalities were detected in only 11.6% of patients. These findings indicate that objective evidence of myocardial injury or ventricular dysfunction was limited to a relatively small subgroup. Comparable observations were reported by Lee and Chen (2015), who noted that most patients with myocardial bridging have normal resting electrocardiograms and preserved ventricular function, whereas ischemic electrocardiographic changes occur mainly in patients with hemodynamically significant bridges (21).

Hemodynamic assessment demonstrated that 80.0% of patients had less than 70% systolic compression, while only 8.7% exhibited greater than 70% systolic compression with persistent diastolic compression. Schwarz Type A constituted 77.3% of cases, followed by Type B (12.8%) and Type C (9.9%). These findings are in agreement with Schwarz et al. (1996) and Ge et al. (1994), who showed that persistent diastolic compression and impaired coronary flow reserve are more important determinants of myocardial ischemia than systolic narrowing alone (19,22).

Angiographically, the left anterior descending artery was involved in 99.7% of patients, predominantly affecting the mid-segment (77.3%), with a mean bridge length of 20.1 ± 6.8 mm. Similar anatomical distribution has been consistently reported by Ferreira et al. (1991), Corban et al. (2014), and Möhlenkamp et al. (2002), all of whom identified the mid-LAD as the most frequent site of myocardial bridging (18,17,23). Coronary artery disease was present in only 13.4% of patients, with proximal coronary involvement being more common than distal disease. This observation supports the findings of Ishikawa et al. (2011) and Corban et al. (2014), who demonstrated that altered coronary hemodynamics predispose the arterial segment proximal to the myocardial bridge to atherosclerotic plaque formation while the tunneled segment remains relatively protected (24,18). Overall, the present study confirms that myocardial bridging is predominantly a benign anatomical coronary anomaly, with only a minority of patients demonstrating clinically significant hemodynamic compromise or associated coronary artery disease.

CONCLUSION

The present study demonstrates that myocardial bridging is predominantly a benign congenital coronary anomaly encountered mainly in middle-aged and elderly patients undergoing invasive coronary angiography. The left anterior descending artery, particularly its mid-segment, was the most frequently involved vessel, with a mean bridge length of 20.1 ± 6.8 mm. Most patients exhibited mild-to-moderate hemodynamic involvement, characterized by less than 70% systolic compression and Schwarz Type A classification, indicating limited physiological significance. Typical angina was the most common clinical presentation, although nearly half of the patients had atypical symptoms or incidentally detected myocardial bridging. Conventional cardiovascular risk factors, particularly hypertension, dyslipidemia, and diabetes mellitus, were frequently present. Concomitant coronary artery disease was identified in a relatively small proportion of patients and was more commonly located proximal to the bridged segment. Overall, comprehensive angiographic and hemodynamic assessment is essential to distinguish incidental myocardial bridging from clinically significant disease, thereby facilitating appropriate

risk stratification and individualized patient management.

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