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Original Article

Myocardial bridging ‘a double-edged sword’: Analysis and significance

Divia Paul A.[a,*], Ramakrishna Avadhani[a], Subramanyam K.[b]

[a] Department of Anatomy, Yenepoya Medical College, Yenepoya University, Deralakatte, 575018, Karnataka, India
[b] Department of Cardiology, K.S Hegde Medical Academy and Hospital, Deralakatte, 575018, Karnataka, India

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ABSTRACT

Introduction: Myocardial bridging (MB) in coronary artery exhibits a role of a double-edged sword in coronary artery disease (CAD). The objectives under study were to validate the prevalence and segments of coronaries with myocardial bridging, length and diameter of bridging segments and cardiac dominance patterns among a west coastal population of Kerala and Karnataka, India from coronary angiogram reports. The co-relation of bridged segments and cardiac dominance patterns in diseased and non-diseased coronary arteries were assessed to find out the significance of both in CAD.
Materials and Methods: The angiograms were obtained from K.S Hegde Medical Academy and Hospital, Karnataka after procuring the ethical clearance. 1000 cases with clinical symptoms, ECG abnormalities were studied prospectively. Recanalized normal looking coronary arteries were excluded.
Results: Myocardial bridging were seen in 50 cases with majority involvement of mid-segment of the left anterior descending artery (LAD). Mean $\pm$ S.D for the length of bridged segments can be expressed as 17.96 ± 9.79 mm for upper limit (U.L) and 14.51 ± 7.56 mm for lower limit (L.L) respectively. Cardiac dominance was seen as right in 863 cases, left in 77 cases, co-dominant in 60 cases. 629 patients had diseased coronaries among the study group. Out of the 50 bridged coronaries, eleven cases had stenosis among bridged segments
Discussion and conclusion: Significant association ($p < 0.001$) which indicated a chance of occurrence of stenosis in the bridged segment or in the artery were bridging is present; if bridge involvement percentage is less than 15% in a coronary artery.

1. Introduction

The right and left coronary arteries arise from the ascending aorta in its anterior and left posterior sinuses. Three major coronary arteries customarily sequel along the epicardial surface of heart. Occasionally, short moieties of coronary artery dip into the myocardium for a variable distance which is termed as myocardial bridging. This has a prevalence of 5% to 12% among patients and is usually confined to the left anterior descending (LAD).[1] Myocardial bridging has an idiosyncratic presentation on angiography. The bridged segment exhibits a normal calibre during diastole and precipitously constricts with each systole.[2] Analysis of the significance of myocardial bridging by coronary angiogram showed that even though tunnelling provides an atheroprotective locale, atherosclerosis will become an axiomatic phenomenon in a segment proximal to the bridged segment. Bridging alters the micro and macro coronary mechanics and also lure and inveigle atherosclerosis at the same time.[3] Studies regarding this aspect have not shown any consistent result as their sample size was small. This study will aid in providing reliable data to study this association. MB might have a far-reaching role in the safeguarding of distal segments of the bridged arteries from atherosclerosis rather than causing proximal atherosclerosis.[4]

The right coronary artery (RCA) is dominant in 80–85% of patients and nondominant in 7–13% of patients in which the left circumflex artery (LCx) is the dominant vessel. The remaining 2–5% patients have RCA that gives rise to the PDA (posterior descending artery), with LCx artery providing all the postero-lateral branches termed as balanced or codominant circulation.[5] Cardiac dominance patterns and their correlations with atherosclerotic prominence give a better understanding of its clinical significance. Though left dominant patterns appear to have significantly higher mortality rate; supporting evidence are lacking due to reduced sample size. In this context, the present study outlooks the incidence of right, left and co-dominance patterns in a broader aspect.

* Corresponding author.
E-mail addresses: divia_manoj@yahoo.com (D.P. A.), rkavadhani@rediffmail.com (R. Avadhani), drsubramanyam@rediffmail.com (S. K.).

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The study was aimed to find out the prevalence and significance of myocardial bridging among a west coastal population of Kerala and Karnataka. The objectives under study were to evaluate the segments involved in bridging and percentage of distribution of bridging in coronary arteries, to assess the morphology of bridged segments in patients with myocardial bridging among coronary arteries, to find the correlation of cardiac dominance pattern to bridging segments, to find the distribution of normal and tunnelled segments among diseased and non-diseased coronary arteries, to validate the quantitative data obtained as a protective mechanism against atherosclerosis or as a risk factor to cause coronary artery diseases.

2. Materials and methods

2.1. Study design

A cross-sectional study was conducted.

2.2. Study setting

After procuring the ethical clearance coronary angiogram reports of one thousand patients were studied prospectively for a period of 9 months. This study protocol conforms to the ethical guidelines as reflected in a priori approval by the institution's human research committee of the centre involved in the study.

2.3. Study subjects

The age group of the study population was given a cut-off at 75 years due to marginal benefits marked during the follow-ups. Hence conservative approach is proven appropriate for the above mentioned age which itself indicates a poor prognosis with an average yearly mortality rate of 33%–35%.[6]

2.3.1. Inclusion criteria

All patients who had undergone through a percutaneous coronary angiographic procedure due to abnormalities in the normal cardiac parameters were selected for the study purpose after obtaining their Informed consent.

2.3.2. Exclusion criteria

Patients with previous history of a coronary artery bypass grafting (CABG) and recanalized normal looking coronary arteries with or without in-stent restenosis coronary arteries were excluded.

2.4. Sample size and its calculation

One thousand samples were estimated statistically for conducting the study.

The sample size was estimated by consulting a statistician and using the statistical software G* Power 3.0.10

2.5. Sampling technique

Convenience sampling was done. Patients will be approached at the cath lab prior to angiogram procedure.

2.6. Data collection

Calibration of the Quantitative Coronary Angiography (QCA) [7,8] systems was carried out by the method in which the coronary catheter is employed by automated edge detection technique resulting in corresponding calibration factors (mm/pixel). The vessel contour was detected by operator independent edge detection algorithms. The dimension of the coronary artery with a bridge was then measured as a function of the catheter diameter. The absolute diameter in mm was calculated by the computerized software analysis performed using the automated coronary analysis package of the Innova 2100 IQ Cath at a AW4.4 workstation. All angiograms were reviewed by two cardiologists using the double blinding method of randomisation for subsequent quantitative analysis. The vessels were assessed in an end diastolic frame for bridge length and diastolic measurements.

2.6.1. Measurement of a bridged segment

Bridging is usually confined to the left anterior descending (LAD) artery.[1] The bridged segment exhibits a normal calibre during diastole and precipitously constricts with each systole.[2] Right anterior oblique (RAO) cranial view displays the proximal, middle, distal segment of the LAD and allows separation of the

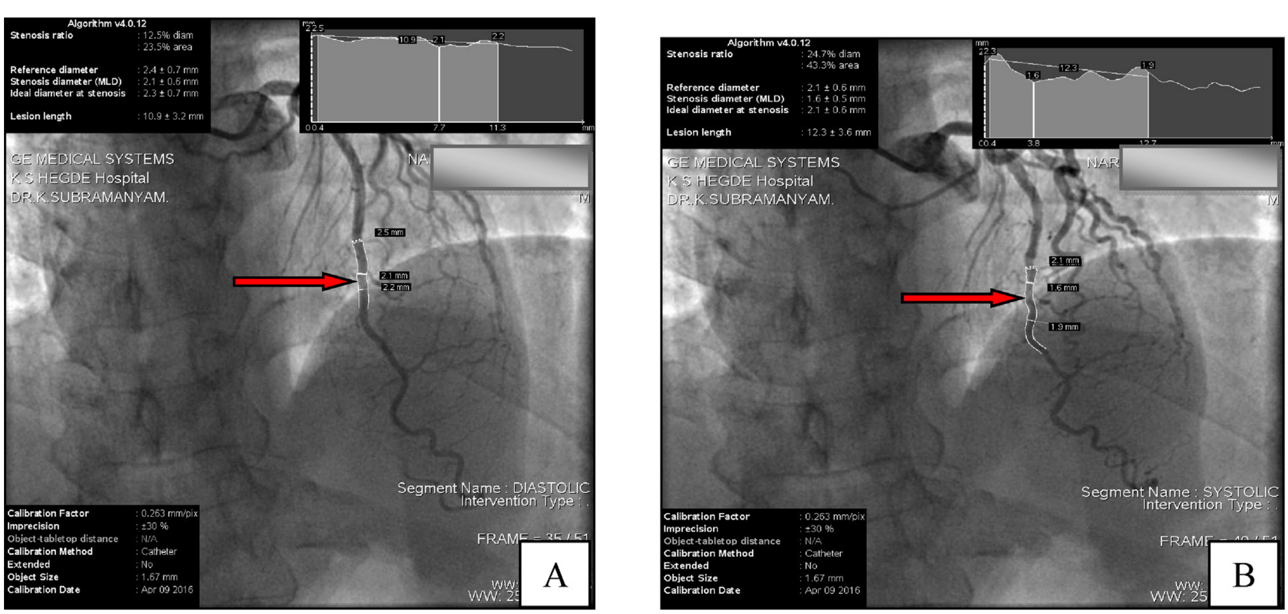


Fig. 1. Diastolic (A) and Systolic (B) phase of bridging.

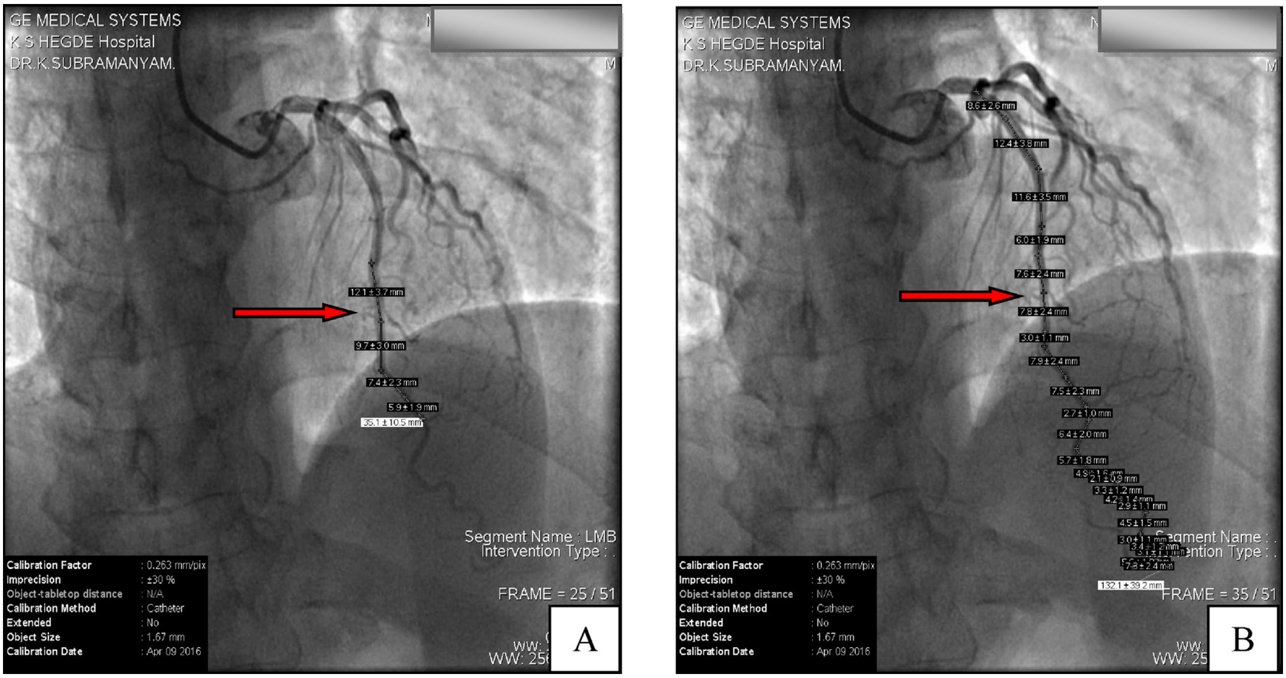


Fig. 2. Length of bridged segment (A) and Left anterior descending artery (LAD) length with bridge (B).

diagonal branches superiorly and the septal branches inferiorly. The anteroposterior (AP) view requiring cranial (20 to 40 degrees) skew often projects the mid portion of the LAD, separating the vessel from its diagonal and septal branches. The RAO caudal projection is also used for visualization of the distal LAD and its apical termination.[5] In the case of bridges present in the left circumflex artery or right coronary artery, the appropriate views were selected accordingly to visualise a bridged segment (Fig. 1).

Bridged coronary arteries were documented for its location, diameter of the bridged segment in both systolic and diastolic phase. This is done to assess the percentage of narrowing in the artery during systole. The maximum diameter region will be taken for assessment in case of diastolic and a minimum diameter in the case of systolic calibration. The length of a bridged segment will be noted down as well as the whole length of the artery in which bridging is present will also be documented (Fig. 2). The percentage of bridging in the artery can be assessed using these parameters. Normal or diseased segment among bridging will be noted if present.

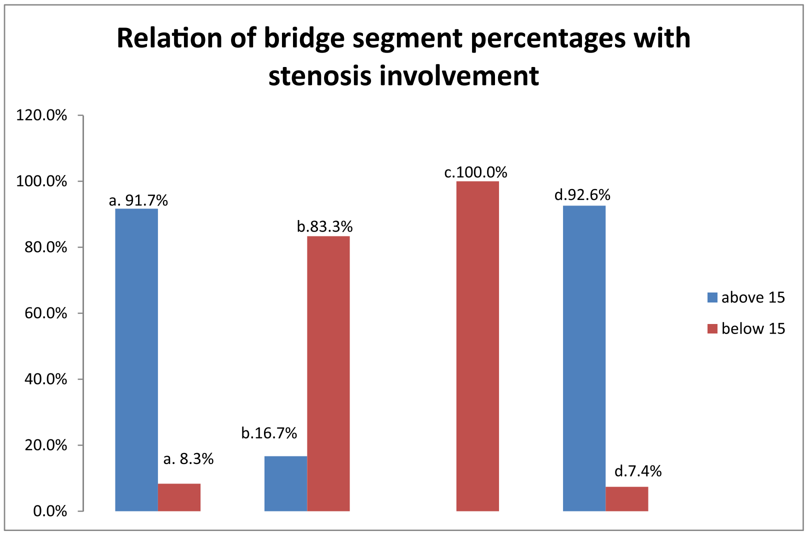
2.6.2. Coronary dominance patterns and assessment

The origin of the PDA and the posterolateral branches are best evaluated in the left anterior oblique (LAO) cranial or anteroposterior (AP) cranial view for right dominance.[5] If the left circumflex

Table 1
Association between categorised bridge coronary artery segments and percentage involvement of stenosis (n = 50).

Sl.no	Categorisation of bridged segments		BL% in TCAL		Total
			Above 15% (a1)	Below 15% (b1)	
a.	BDDOS	n 1	11	1	12
		Percentage among diseased segments (n = 23 – n1 + n2 + n3)	91.70%	8.30%	100.00%
		Percentage among BL% in TCAL	29.70%	7.70%	24.00%
b.	BSD	n 2	1	5	6
		Percentage among diseased segments (n = 23 – n1 + n2 + n3)	16.70%	83.30%	100.00%
		Percentage among BL% in TCAL	2.70%	38.50%	12.00%
c.	Both (BDDOS and BSD)	n 3	0	5	5
		Percentage among diseased segments (n = 23 – n1 + n2 + n3)	0.00%	100.00%	100.00%
		Percentage among BL% in TCAL	0.00%	38.50%	10.00%
d.	Normal and bridged (NB)	n 4	25	2	27
		Percentage among diseased segments (n = 27 – n 4 only)	92.60%	7.40%	100.00%
		Percentage among BL% in TCAL	67.60%	15.40%	54.00%
e.	Total	n 5(a1 + b1)	37	13	50
		Percentage among diseased segments	74.00%	26.00%	100.00%
		Percentage among BL% in TCAL	100.00%	100.00%	100.00%

Abbreviations used: Normal Bridging segment with stenosis in other segments of coronary artery (**BDDOS**); Bridged and stenosis in bridged segment (**BSD**); 3. **Both** (**BDDOS and BSD**) Normal and bridged coronary artery with no stenosis (**NB**); **BL% in TCAL:** Bridge length percentage in total coronary artery length in which bridging is present; **n**: number; **a1**: Above 15% bridging; **b1**: Below 15% bridging.



Graph 1. a. Normal Bridging segment with stenosis in other segments of coronary artery **(BDDOS)**,b. Bridged and stenosis in bridged segment **(BSD),** c. Both **(BDDOS and BSD)**, d. Normal and bridged coronary artery with no stenosis **(NB)**.

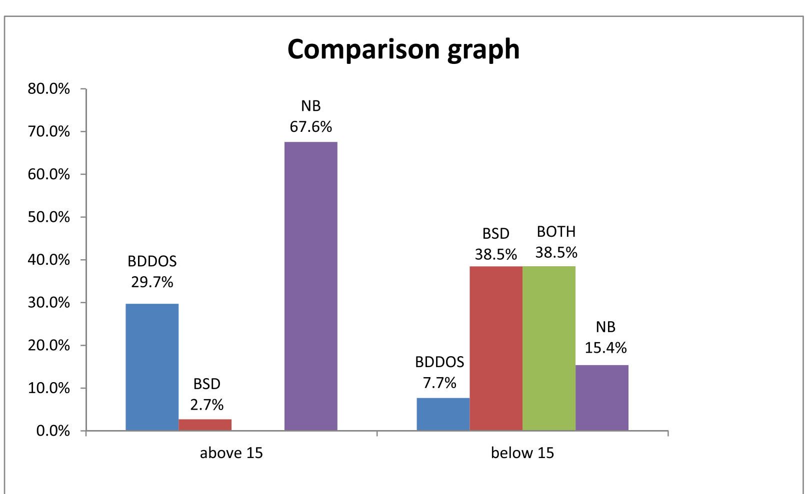
artery (LCx) is dominant, the optimal projection for the left posterior descending artery (PDA) is the left anterior oblique (LAO) cranial view. Left anterior oblique (LAO) cranial or anteroposterior (AP) cranial view gives an optimal projection to observe the co-dominance[5]. The co-relation of cardiac dominance pattern to bridging segments as well as normal or diseased segment among each dominant pattern was noted down.

3. Results

Presence of myocardial bridging was seen in 50 (5%) cases. Majority of bridges were seen in mid segment of left anterior descending artery (LAD) among thirty seven (37) cases of type lll variety.[5] Distal segment bridges of left anterior descending artery (LAD) were seen in ten (10) cases. Remaining three (3) cases involved two (2) cases of mid-segment of right coronary artery and a case of the distal segment of ramus branch with bridging. Mean ± standard deviation (S.D) for the length of bridged segments can be expressed as 17.96 ± 9.79 mm for upper limit (U.L) and 14.51 ±7.56 mm for lower limit (L.L) respectively. Mean ± S.D for the length of artery segments with bridging can be expressed as 117.41 ± 23.78 mm for upper limit (U.L) and 97.8 ± 15.15 mm for lower limit (L.L) respectively. Mean ± S.D for systole and diastole artery diameter can be expressed as 1.2 ± 0.36 and 2.2 ± 0.49 mm respectively (Table 3 Row 7). The difference between artery diameter in diastole and systole ranges from 0.3 mm to 3.3 mm with Mean ± S.D of 1 ± 0.54 mm. Cardiac dominance was seen as right in 863 (863/1000–86.3%) cases, left in 77 (77/1000–7.7%) cases, co-dominant in 60 (60/1000–6%) cases (Table 4 Row 1). Among bridged segments (n = 50), 43 were right, 2 were left and 5 were co-dominant. 629 patients had diseased coronaries among the study group. Out of this 534 (534/863–61.9%) were right, 63 (63/77–81.8%) were left and 32 (32/60–53.3%) were co-dominant respectively. Among fifty bridged coronaries 23 had diseased coronaries out of that 18 were right, 1 was left and 4 were co-dominant respectively.

3.1. Abbreviations used

a. Normal Bridging segment with stenosis in other segments of coronary artery (BDDOS) b. Bridged and stenosis in bridged segment



Graph 2. Comparison of percentage of bridge length in total coronary artery length. a. Normal Bridging segment with stenosis in other segments of coronary artery **(BDDOS)**, b. Bridged and stenosis in bridged segment **(BSD)**, c. Both **(BDDOS and BSD)**, d. Normal and bridged coronary artery with no stenosis **(NB)**.

Table 2
Association between percentage of bridging and stenosis involvement.

	γ2 Value	Degrees of freedom	p- value
Association test	31.279[a]	3	<0.001*

Interpretation: When chi-square test was done to find the association, a result of $\gamma^2 = 31.279$, Degrees of freedom (d.f) = 3, $p < 0.001^*$ were obtained. Since $p<0.001^*$, this indicates an association between percentage of bridging and stenosis involvement of the artery with bridging.
Statistical test used: ***Chi-square test***

(BSD) c. Both (BDDOS and BSD) d. Normal and bridged coronary artery with no stenosis (NB)

3.2. Descriptive statistics

Among fifty (n = 50) bridged coronary arteries 23 (23/50–46%) had diseased coronaries [BDDOS + BSD + (BDDOS + BSD)]; out of that 6 (6/50–12%) had stenosis in bridged segments (BSD) itself. (Table 1 Row 2) Analysing the percentage of bridging present in the artery among BSD patients (n = 6); it was found that n = 5 (5/6–83.3%) of patients with disease in the bridged segments were having less than 15% bridging and (n = 1) (1/6–16.7%) had more than 15% bridging. (Table 1 Row 2). If the disease were in the other coronary segments (BDDOS) in which bridged segment were normal (BSD) (n = 11) (11/12–91.7%) had more than 15% of bridging percentage in the involved artery and (n = 1) (1/12–8.3%) had less than 15% of bridging (Table 1 Row 1).

If both bridged segments and other segments of coronary arteries (BDDOS + BSD) were included in stenosis; (n = 5)(5/5–100.0%) of patients with disease in the bridged segments(BSD) among BDDOS + BSD group were having less than 15% bridging of the involved artery in which bridging was present(Table 1 Row 3). Among normal patients with bridge (NB) (n = 25) (25/27–92.6%) had more than 15% of bridging and n = 2 (2/27–7.4%) less than 15% bridging in the total length of artery involved in bridging (Table 1 Row 4) (Graphs 1 and 2).

Chi-square test for association between percentage of bridging and stenosis involvement among bridged segments was done. A significant association ($p < 0.001^*$) were obtained which indicated when bridge involvement percentage is less than 15% in an artery in which it is present there is a chance of occurrence of disease in bridge segment or in the artery were bridging is present. A significant association between disease involvement and percentage of the bridge were found (Table 2).

4. Discussion

Out of 23 patients with diseased coronaries [(BDDOS) + (BSD) + (BDDOS + BSD)], eleven patients (11/23–47.8%) were categorised under [(BSD) + (BDDOS + BSD)] (Table 1 Row 2 and 3). Angiogram reports revealed that 10 (10/11–90.9%) had stenosis extending from the proximal segment above the bridge into the bridged segment. Three (n = 3) patients with bridge segment stenosis had undergone percutaneous transluminal coronary angioplasty (PTCA) and stenting at their own risk even after briefing the complications behind the same. The incidence of perforation (n = 3) during PTCA was more in a bridged segment stent implantation compared to other non-bridged diseased segments. These views support that use of sirolimus-eluting stents to treat atherosclerotic lesions in coronary arteries with bridging can result in major adverse cardiovascular events when compared to patients with stenosis in the non-bridged segments of the coronary artery.

Alegria et al. reported the prevalence of myocardial bridging has a 5% to 12% among patients and is usually confined to the left anterior descending (LAD).[1] Chatzizisis et al. found that the mid left anterior descending artery (LAD) was the most common coronary artery involved in bridging.[9] Mann et al. mentioned about the incidence percentages and locations of myocardial bridging in their study. The prevalence of bridging was observed as 10.4% with its commonest location being mid-left anterior descending coronary artery in most cases.[5]

The present study indicated the prevalence percentage of myocardial bridging as 5% and the frequent location involved in bridging as mid left anterior descending artery (LAD) which correlates with the above- mentioned study results.

Zeina et al. stated that the surrounding myocardium initiates an idiosyncratic atheroprotective hemodynamic microenvironment within bridges even though the mechanisms induced for this initiation uniqueness are largely unknown.[10] Donkol et al. encountered the prevalence of myocardial bridges as 22.5% with most of the intramuscular segments were of the superficial type. All bridges were confirmed to the mid left anterior descending (LAD) artery (24.6%).[11]

The present study indicated the prevalence percentage of myocardial bridging as 5% which is less compared to the above-mentioned study. But bridges were more predominantly observed in mid left anterior descending artery (LAD) which is similar to the above-mentioned study result.

Mann et al. mentioned about characteristics of myocardial bridging in terms of its location, length, and depth. The average

Table 3
Comparison of present study with studies of other authors with topic of same discipline.

Sl.no.	Authors and Views	Bridge Length		Bridge Depth	
1	Mann [5]	23.4 mm		2.6 mm	
2	Hwang et al. [12]	Superficial	16.4 ± 8.6mm	3.0 ± 1.4 mm	
		Deep	27.6 ± 12.8 mm		
3	Jeong et al. [13]	For systole – regression(r)of 0.394, p-value of 0.028 For diastole- r = 0.524, p-value of 0.001		Systole 1.3 ± 0.3 mm and 1.2 ± 0.5 mm	Diastole 1.4 ± 0.4 mm and 1.6 ± 0.6 mm
4.	Jodocy et al.[14]	14.9 ± 6.5nmm		2.6 ± 1.6 mm	
5.	Bayrak et al[4]	14 ± 7 mm		1.6 ± 11 mm	
6.	Zeina et al.[10]	Overall	19.5 ± 5.7 mm	2 ± 0.6 mm	
		Normal to mild	18 ± 5.6 mm	1.8 ± 0.7nmm	
		Moderate to severe	22.9 ± 4.5mm	2.3 ± 0.7 mm	
7.	Present study	Upper limit of artery dimension (U. L)	Lower limit of artery dimension (L. L)	Bridge diameter	
		17.96 ± 9.79 mm	14.51 ± 7.56 mm	Systole Mean ± S.D 1.2 ±n0.36 mm Difference = 0.3mm to 3.3mm Mean ± S.D of 1 ± 0.54mm	Diastole Mean ± S.D 2.2 ± 0.49 mm

Table 4
Coronary dominance patterns and comparisons.

Sl. No.	Different authors and corresponding studies	Coronary Dominance		
		Right	Left	Co-dominant
1.	**Present study**	**86.3%**	**7.7%**	**6%**
2.	Kosar [20]	76%	9.1%	14.8%
3.	Reagan[21]	85%	7%–8%	7%–8%.

myocardial bridge length and depth were found as 23.4 mm and 2.6 mm respectively (Table 3 Row 1).[5] The incidence for the occurrence of atherosclerotic plaques were assessed as 16% in its proximal segments prior to a myocardial bridge (MB) of 2-cm in length reported by Hwang et al. When the mean length of a tunnelled segment was evaluated the superficial myocardial bridges (MB) had an average length of 16.4 ± 8.6 mm and for deep MB's had 27.6 ± 12.8 mm and thickness of 3.0 ± 1.4 mm, respectively (Table 3 Row 2).[12]

When systolic and diastolic phase of myocardial bridges (MB) was assessed for its correlation within the MB diameters on multi-detector computed tomography coronary angiography (MDCT-CA) and computed coronary angiography (CCA) by Jeong et al. showed a significant correlation during systolic (1.3 ± 0.3 mm and 1.2 ± 0.5 mm: *regression(r)of* 0.394, *p-value of* 0.028) and diastolic phases (1.4 ± 0.4 mm and 1.6 ± 0.6 mm: $r = 0.524$, *p-value of* 0.001) (Table 3 Row 3).[13]

The myocardial bridges of the left anterior descending artery (LAD) were common and exhibiting a percentage prevalence of 23% with average length of 14.9 ± 6.5 mm and a depth of 2.6 ± 1.6 mm revealed through the studies of Jodocy et al. A significant difference was noted between the LAD luminal diameter in systole and diastole ($p < 0.001$) with a higher diameter reduction of 27% for end-systole compared to end-diastole with 15% ($p = 0.006$) (Table 3 Row 4).[14] Bayrak et al. evaluated the average length and depth of myocardial bridges (MBs) as 14 ± 7 mm and 1.6 ± 11 mm respectively (Table 3 Row 5). Prevalence of atherosclerotic plaques at the distal left anterior descending artery (LAD) was 3.5% which was significantly lower (*p*-value: 0.0001) in patients with MB on the middle LAD 19.7%.[4]

Zeina et al. visualised the overall mean length of a bridge segment as 19.5 ± 5.7 mm (range, 8–30 mm) and the maximum myocardial thickness overlying the bridge termed as depth was 2 ± 0.6 mm (range, 1–3.1 mm) respectively. If the mean length and mean thickness of the bridge in subjects with left anterior descending artery (LAD) myocardial bridge (MB) is 18 ± 5.6 mm and 1.8 ± 0.7 mm, it can be categorized as normal to mild. In subjects who were categorized as moderate to severe were having 22.9 ± 4.5 mm and 2.3 ± 0.37 mm of mean length and mean thickness of the bridge based on coronary computed tomographic angiography (CCTA) assessments (Table 3 Row 6). A significant difference was found between these two groups regarding the mean length ($p < 0.0002$) and thickness ($p < 0.0014$) of the bridge.[10] Mohlenkamp et al. found that the presence of stenosis in the left anterior descending artery (LAD) proximal to the myocardial bridge when correlated with the bridge diameter and its length.[15]

In the present study, the prevalence of myocardial bridging was 5% and average myocardial bridge length was 17.96 ± 9.79 mm for upper limit (U.L) and 14.51 ±7.56 mm for lower limit (L.L) respectively. Mean ± S.D for systole and diastole diameter can be expressed as 1.2 ± 0.36 mm and 2.2 ± 0.49 mm respectively. The difference between diastole and systole ranges from 0.3 mm to 3.3 mm with Mean ± S.D of 1 ± 0.54 mm. (Table 3 Row 7)

Ghaffari et al. stated that left coronary dominance and atherosclerotic involvement of left anterior descending artery (LAD) is neither related nor left coronary dominance is associated with atherosclerotic involvement of LAD ostium and ischemic myocardial infarction.[16] A study to find a relationship between coronary arterial dominance and the extent of coronary artery disease by Vasheghani-Farahani et al. reported a relationship between angiographic coronary artery disease (CAD) severity, arterial territory involvement and dominance patterns.[17] Dominance exhibits a significant role in inferior wall infarcts and in that left dominant patterns appears to have significantly higher mortality revealed by Goldberg A et al. and Amin et al.[18,19]

The complex anatomy of the coronary artery system can accurately be depicted by 64-slice computed tomographic angiography (CTA). The coronary artery system was right dominant in 76%, left dominant in 9.1% and co-dominant in 14.8% of the cases has been reported by Kosar et al. (Table 4Row 2).[20] Right dominance was observed relatively in 85% of individuals, left dominance and co-dominance was noted down with a prevalence of 7%–8% by Reagan et al. (Table 4 Row 3).[21]

Prevalence of right and left dominance patterns was almost similar to the comparative studies; the co-dominant prevalence was lower in the present study. The present study lines up with this finding as the disease prevalence was more for left dominant patterns, followed by right dominant patterns and least for co-dominant patterns.

No comparative studies were identified to analyse and compare cardiac dominance pattern to bridging segments.

Left coronary dominance and atherosclerotic involvement of left anterior descending artery

(LAD) is neither related nor associated with atherosclerotic involvement of LAD ostium and

Ischemic myocardial infarction stated by Ghaffari et al. [16] But the present study had more stenosis prevalence among left dominant patterns, followed by right and least for co-dominant patterns.

The surrounding myocardium initiates an idiosyncratic atheroprotective hemodynamic microenvironment within bridges even though the mechanisms induced for this initiation uniqueness are largely unknown.[9] The present study reveals that the mechanism which the author points out can be the percentage of bridging present in the artery in which a bridged segment was involved. The comparative studies for analysing the same were not available which indicates the novelty in the present study.

5. Conclusion

When bridge involvement percentage is less than 15% in an artery in which bridge is present there is chance of occurrence of disease in bridge segment or in the artery were bridging is present. The significant association between stenosis involvement and percentage of the bridge was found.

Study limitations

The correlation of superficial and deep bridges to coronary artery disease as well as the presence of stenosis in the left anterior descending (LAD) proximal to the myocardial bridge with the bridge diameter and its length to coronary artery disease involvement strategies were not assessed in the present study.

Atherosclerosis is a common finding in segments proximal to the myocardial bridge (MB), but the prevalence of plaques in equivalent segments in patients with analogous coronary artery disease risk and without MB was not higher.[4]

Conflict of interest

All authors hereby declare that there is no conflict of interest for this manuscript.

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