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Original Research Article

Association of coronary calcium arc on stent expansion in patients with non-ST elevation myocardial infarction by intravascular ultrasound

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ABSTRACT

Background: Coronary calcification indicates atherosclerotic plaque burden and contributes to stent under-expansion, leading to complications like restenosis and thrombosis. The impact of coronary calcium severity on stent expansion in NSTEMI patients remains unexplored in our population. This study aimed to evaluate the association between the coronary calcium arc and stent expansion in patients with non-ST elevation myocardial infarction (NSTEMI) using intravascular ultrasound (IVUS).
Methods: This cross-sectional study was conducted at the National Institute of Cardiovascular Diseases (NICVD), Dhaka, Bangladesh from May 2019 to April 2020. A total of 109 NSTEMI patients undergoing IVUS-guided PCI for calcified lesions at NICVD were enrolled. Based on the calcium arc, 73 patients (0-180°) formed Group I, and 36 (181-270°) formed Group II. Stent expansion was measured. Ethical approval was obtained, and data were analyzed using SPSS version 23.0.
Results: In this study, despite higher balloon pressures in Group II, acute diameter gain (1.5±0.4 mm vs 1.4±0.3 mm, $p<0.03$), acute CSA gain (5.8±1.2 vs 5.3±1.0, $p<0.04$), stent expansion by MLD (95.6±2.9% vs 89.6±3.3%, $p<0.001$), and MLA (92.7±5.1% vs 81.3±6.4%, $p<0.001$) were lower than in Group I. Stent expansion correlated negatively with calcium arc (MLD: $r=-0.66$, $p<0.001$; MLA: $r=-0.69$, $p<0.001$) but not with calcium length (MLD: $r=0.14$, $p=0.1$; MLA: $r=0.09$, $p=0.36$).
Conclusion: Implantation of stents in calcified lesions results in less optimal stent expansion, especially in lesions with thick, eccentric calcific plaque layers.

Keywords: Acute luminal diameter gain, Cardiovascular diseases, Coronary calcium, Luminal CSA gain, Myocardial infarction, Stent length

INTRODUCTION

Cardiovascular diseases (CVDs) remain the leading cause of premature mortality worldwide, accounting for approximately 50% of all non-communicable disease (NCD) deaths annually.[1] In 2016, CVD caused an estimated 17.9 million deaths globally, with ischemic heart disease (IHD) responsible for over eight million fatalities.[1] In Europe alone, IHD contributes to nearly 1.8 million deaths annually, representing 19% of total mortality.[2] In Bangladesh, the prevalence of coronary artery disease (CAD) in rural populations is approximately 4.5%, a rate comparable to that of developed nations. Major risk factors for CAD in this region include male sex, higher socioeconomic status, hypertension, and diabetes.[3]

Additionally, younger individuals exhibit similar risk levels to older populations, emphasizing the necessity for primordial and primary prevention strategies.[1] Non-ST elevation acute coronary syndrome (NSTE-ACS), comprising NSTEMI and unstable angina (UA), has shown a gradual rise in age- and sex-adjusted incidence rates since 1999.[4] Coronary calcification is a well-

established marker of atherosclerotic plaque burden and a major factor in stent under-expansion during PCI, leading to complications such as restenosis and stent thrombosis.[5,6] Proper evaluation of coronary calcification is therefore critical for PCI planning.

High-resolution intravascular optical coherence tomography (IVOCT) has revealed that stent placement in heavily calcified lesions is often suboptimal, leading to noncircular stent deployment, under-expansion, malposition, and calcium fractures, all of which heighten the risk of complications like vessel micro-dissection, thrombosis, and in-stent restenosis.[7]

Studies using grayscale IVUS and optical coherence tomography (OCT) demonstrate that severe calcification is linked to increased acute stent malposition. The circumferential arc of calcium, rather than its depth, primarily influences the degree of malposition.[8] An OCT study of 51 coronary lesions found that the arc angle of calcification, rather than its thickness or length, was the key determinant of lumen gain post-stenting.[9]

Clinically, severe coronary calcification, as assessed by intravascular imaging, restricts stent expansion, increasing the likelihood of restenosis and stent thrombosis, underscoring the importance of pre-emptive lesion modification.[10] Despite these findings, no single intravascular imaging technique-whether grayscale IVUS, radiofrequency IVUS (RF-IVUS), or OCT-has been definitively established as the gold standard for evaluating coronary calcification due to limitations in large-scale, systematic data.

Severely calcified lesions are rare, technically challenging to image pre-intervention, and often require plaque modification strategies such as excimer laser angioplasty, rotational or orbital atherectomy, and cutting/scoring balloon atherectomy before or after stent implantation.[11,12]

Extensive superficial calcifications with an arc ≥180° is a strong indication for pre-stenting adjunctive calcium modification, including rotational or orbital atherectomy or cutting/scoring balloons. A randomized controlled trial found that aggressive plaque preparation using rotational atherectomy (RA) and cutting balloons (CB) was safe and effective for patients with severely calcified lesions, yielding better acute PCI results and clinical outcomes than RA combined with conventional balloon angioplasty.[13]

While a greater calcium arc, length, or thickness is generally associated with stent under-expansion, no definitive thresholds exist for guiding lesion modification strategies before stent placement. Some IVUS analyses, such as those by Costa et al, found no correlation between calcium arc or lesion length and subsequent stent expansion. Similarly, an intravascular ultrasound study of 60 native vessels reported no significant association between acute stent expansion and calcium characteristics such as calcium score, length, maximum thickness, or area.[14] These discrepancies highlight the need for further large-scale studies to establish standardized criteria for optimizing PCI outcomes in severely calcified lesions.

METHODS

This cross-sectional observational study was conducted at the National institute of cardiovascular diseases (NICVD), Dhaka, Bangladesh, from May 2019 to April 2020. A total of 110 patients with non-ST elevation myocardial infarction (NSTEMI) undergoing IVUS-guided percutaneous coronary intervention (PCI) for calcified lesions were enrolled. Of these, 109 patients were divided into two groups based on the calcium arc: Group I (0-180°; n=73) and Group II (181-270°; n=36). Stent expansion was measured in both groups.

Patients with cardiogenic shock, congestive heart failure, STEMI lesions, inaccessible imaging devices, insufficient image quality, stent thrombosis, in-stent restenosis, coronary artery bypass grafting (CABG), or a calcium arc ≥270° were excluded. The ethical committee of NICVD approved the study, and data were analyzed using SPSS version 23.0.

RESULTS

In this study, 109 patients were enrolled, including 73 in Group I (calcium arc 0-180°) and 36 in Group II (calcium arc 181-270°). The mean age was 53.4±9.8 years, with Group I averaging 51.9±9.7 years and Group II 56.4±9.7 years. Older patients tended to have a higher degree of coronary calcification (p=0.03).

No significant difference in calcification location was found between the groups. Key IVUS parameters, such as the arc and length of calcium, proximal reference diameter, and average reference diameter, were significantly higher in Group II (p<0.05).

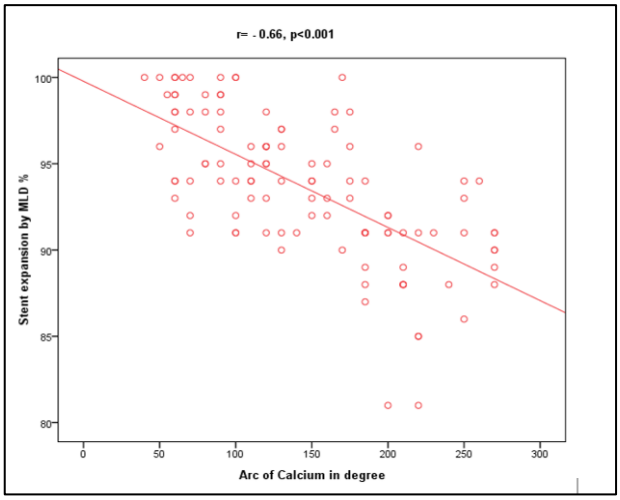

Figure 1: Correlation between stent expansion by MLD and arc of calcium.

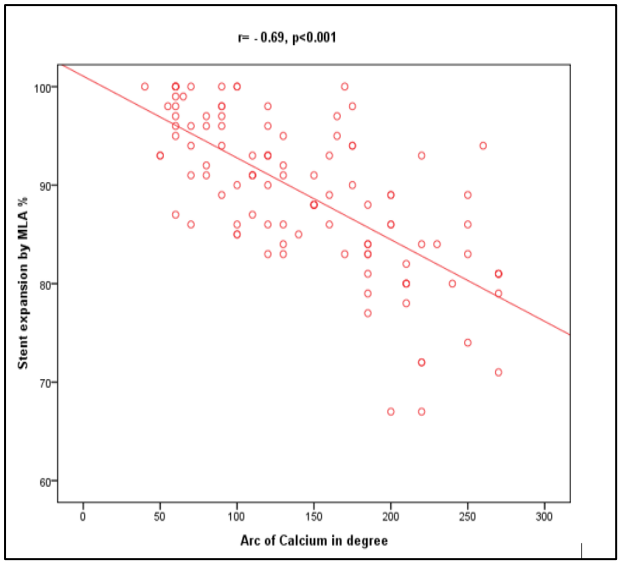

Figure 2: Correlation between stent expansion by MLA and arc of calcium.

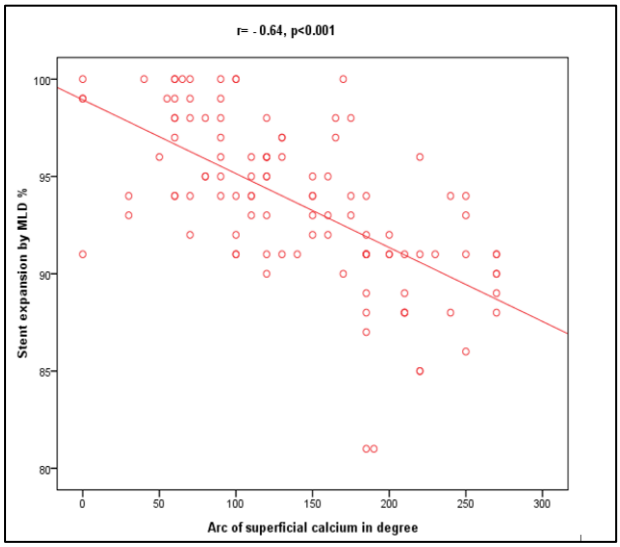

Figure 3: Correlation between stent expansion by MLD and arc of superficial calcium.

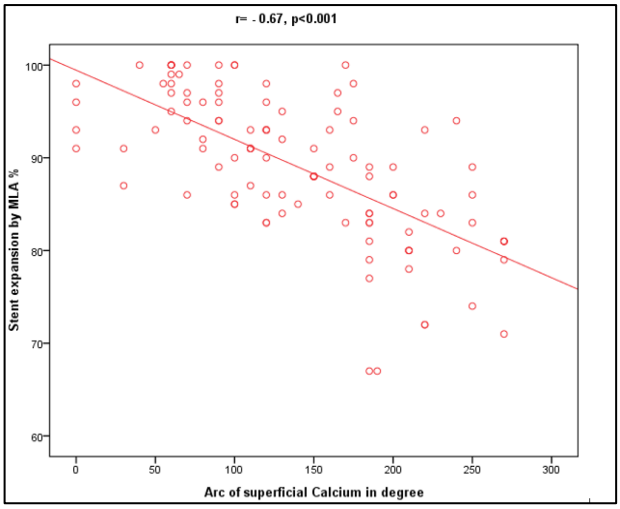

Figure 4: Correlation between stent expansion by MLA and arc of superficial calcium

However, distal reference diameter and lesion length showed no significant difference (p>0.05). Stent expansion, measured by acute luminal diameter gain, acute luminal CSA gain, MLD, and MLA, was significantly higher in Group I (p<0.05). Maximal balloon size and pressure were greater in Group II (p<0.05). Minimal lumen diameter was insignificantly higher in Group I (p=0.23) before PCI but significantly higher post-PCI (p=0.03). Lumen CSA and CSA stenosis showed no significant difference pre-PCI, but post-PCI stenosis was higher in Group II (p=0.002 and <0.001, respectively). A moderate negative correlation was observed between stent expansion (by MLD and MLA) and the arc of calcium (p<0.001), as well as with the arc of superficial calcium (p<0.001). However, the correlation between stent expansion and the length of calcification was negligible (p=0.36). Significant associations with stent expansion by MLA were found for actual luminal diameter gain, luminal CSA gain, maximal balloon size, maximal balloon pressure, and the arc of superficial calcium. Other variables also showed associations, though not reaching statistical significance.

Table 1: Age distribution of participants (n=109)

Age (in years)	Group I (n=73)		Group II (n=36)		Total (n=109)		P value
	N	%	N	%	N	%	
<50	36	49.30	13	36.40	49	45.0	
≥50	37	50.70	23	63.90	60	55.0	0.03[s]
Mean±SD	51.9±9.7		56.4±9.7		53.4±9.8		

s-significant.

Table 2: Distribution of cases by location of calcification (n=109).

Location	Group I		Group II		Total		P value
	N	%	N	%	N	%	
Superficial	67	91.80	33	91.70	100	91.70	0.98[ns]
Deep	4	5.50	0	0	4	3.70	0.15[ns]
Both	2	2.70	3	8.30	5	4.60	0.18[ns]

ns=non-significant.

Table 3: Comparison of pre-PCI intravascular ultrasound measurements between two groups (n=109)

IVUS characteristics	Group I	Group II	P value
	Mean±SD	Mean±SD	
Arc of calcium at the lesion site (º)	106.7±38.4	221.7±30.7	<0.001[s]
Arc of superficial calcium at the lesion site (º)	99.8±45.0	219.4±31.3	<0.001[s]
Length of calcification (mm)	7.3±4.6	9.9±6.3	0.01[s]
Proximal reference diameter (mm)	3.6±0.4	3.8±0.3	0.002[s]
Distal reference diameter (mm)	3.2±0.4	3.2±0.4	0.76[ns]
Average reference diameter (mm)	3.3±0.3	3.5±0.3	0.002[s]
Reference CSA (mm^2)	8.6±1.9	9.8±1.4	0.002[s]
Lesion length (mm)	29.6±8.5	32.0±7.0	0.14[ns]

s-significant; ns=non-significant.

Table 4: Comparison of post-PCI intravascular ultrasound measurements between two groups (n=109).

IVUS characteristics	Group I (n=73)	Group II (n=36)	P value
	Mean±SD	Mean±SD	
Stent length (mm)	33.6±8.7	35.9±7.3	0.16[ns]
Acute luminal diameter gain (mm)	1.5±0.4	1.4±0.3	0.03[s]
Acute luminal CSA gain(mm^2)	5.8±1.2	5.3±1.0	0.04[s]
Stent expansion by MLD (%)	95.6±2.9	89.6±3.3	<0.001[s]
Stent expansion by MLA (%)	92.7±5.1	81.3±6.4	<0.001[s]
Maximal balloon size (mm)	3.6±0.4	3.9±0.3	0.002[s]
Maximal balloon pressure (atm)	15.1±1.3	18.5±1.4	<0.001[s]

s-significant; ns=non-significant.

Table 5: Comparison of intravascular measurements in patients pre and post PCI (n=109).

IVUS characteristics	Pre PCI			Post PCI		
	Group I (n=73)	Group II (n=36)	P value	Group 1 (n=73)	Group II (n=36)	P value
Minimal lumen diameter (mm)	1.9±0.3	1.8±0.3	0.23[ns]	3.4±0.5	3.0±0.2	0.03[s]
Lumen CSA (mm^2)	2.8±0.8	2.6±0.8	0.30[ns]	8.2±1.7	7.9±1.0	0.33[ns]
CSA stenosis (%)	71.9±6.7	76.2±7.1	0.002[s]	7.1±5.1	18.7±6.6	<0.001[s]

s-significant; ns=non-significant.

Table 6: Multiple linear regression analysis to determinants on stent expansion by MLA (n=109).

Variables	Coefficients			t	P value
	Unstandardized		Standardized		
	B	Std. Error	β		
(Constant)	112.358	11.802		9.52	<0.001[s]
Age (in years)	-0.016	0.049	-0.02	-0.32	0.75[ns]
Smoking	1.032	1.186	0.059	0.871	0.38[ns]
Length of calcification (mm)	0.039	0.089	0.027	0.437	0.66[ns]
Proximal reference diameter (mm)	0.25	1.683	0.011	0.148	0.88[ns]
Average reference diameter (mm)	-1.194	6.347	-0.05	-0.188	0.85[ns]
Reference CSA (mm^2)	-1.339	1.156	-0.299	-1.158	0.25[ns]
Acute luminal diameter gain (mm)	-5.158	2.689	-0.176	-1.919	0.04[s]
Acute luminal CSA gain (mm^2)	2.126	0.728	0.315	2.922	0.01[s]
Maximal balloon size (mm)	8.223	1.843	0.41	4.462	<0.001[s]
Maximal balloon pressure (atm)	-2.441	0.415	-0.65	-5.885	<0.001[s]
Arc of superficial calcium at the lesion site (º)	-2.101	0.389	-0.501	-4.561	<0.001[s]
Arc of calcium at the lesion site (º)	-3.251	0.456	-0.759	-6.285	<0.001[s]

s-significant; ns=non-significant.

DISCUSSION

In this study, the mean age was 51.9 ± 9.7 years in Group I and 56.4 ± 9.7 years in Group II, with a statistically significant difference (p = 0.03). Similar age distributions were reported in previous studies, including one at NICVD on 637 CAD patients15 and another with 200 NSTEMI patients.16 In terms of gender distribution, 86.3% of Group I and 91.7% of Group II were male, resulting in a male-to-female ratio of 2.02:1. This is higher than the national ratio of 1.002:1.17 Although male patients were predominant in both groups, no significant gender difference was observed (p = 0.42), with fewer females likely due to limited access to healthcare or socio-cultural factors affecting women. In Bangladesh, studies consistently report a male predominance in IHD cases.15 Smoking, a common IHD risk factor, is less prevalent among females, which may further explain the male dominance.

In this study, risk factors such as hypertension, dyslipidemia, diabetes mellitus (DM), and family history of CAD did not show significant differences between Group I and Group II, except for smoking. The smoking rate was 19.2% in Group I and 38.9% in Group II, with a statistically significant difference (p=0.03). Similar risk factor distributions were observed in a study by Chowdhury et al, while Kalyoncuoglu et al and Durmus et al found no significant differences, and Karabag et al reported significant differences in hypertension and DM prevalence.[16,18,19]

In this study, the mean arc of superficial calcium at the lesion site was 106.7±38.4 in Group I and 221.7±30.7 in Group II, with a statistically significant difference (p<0.001). These findings were similar to those of Hoffmann et al who reported values of 1070±300 and 2170±270 in their respective groups (p<0.001).[20]

Additionally, Group II had significantly higher values for arc of calcium, length of calcification, proximal reference diameter, average reference diameter, and reference CSA compared to Group I (p < 0.05). However, distal reference diameter and lesion length showed no significant differences between the groups (p>0.05). These results align with findings from Vavuranakis et al.[21] In this study, the mean acute luminal diameter gain was 1.5±0.4 mm in Group I and 1.4±0.3 mm in Group II, with a statistically significant difference (p<0.03). The mean acute luminal CSA gain was 5.8±1.2 mm in Group I and 5.3±1.0 mm in Group II, also with a statistically significant difference (p<0.04).

These findings were similar to those of Hoffmann et al who reported mean acute diameter gains of 1.91±0.46 and 1.8±0.56, and mean acute CSA gains of 5.1±2.3 and 4.4±1.9 in Group I and Group II, respectively, with p values of <0.0067 and <0.041.[20] The results were consistent with those of Vavuranakis et al.[21] In this study, the mean stent expansion by MLD was 95.6±2.9% in Group I and 89.6±3.3% in Group II, with a statistically significant difference (p<0.001). The mean stent expansion by MLA was 92.7±5.1 in Group I and 81.3±6.4 in Group II, also showing a statistically significant difference (p<0.001). Similarly, Kobayashi et al reported a significant difference between the groups (p<0.02). The maximal balloon pressure applied for stent expansion with increasing arc of calcification was 15.1±1.3 atm in Group I and 18.5±1.4 atm in Group II (p<0.001). Vavuranakis et al found that high-pressure balloon inflations in moderate-severe calcified lesions increased stent expansion (59%, p=0.0036), but reduced symmetry (48%, p=0.0045). In this study, a moderate negative correlation was found between stent expansion by MLD and arc of calcium (r=-0.66, p<0.001) and between stent expansion by MLA and arc of calcium (r=-0.69, p<0.001). These findings align with Vavuranakis et al who reported an inverse correlation between stent expansion and arc of calcium (r=-0.8, p<0.0001).[20,21]

However, no statistically significant correlation was found between stent expansion by MLD and lengths of calcium (r=0.14, p=0.16), nor between stent expansion by MLA and lengths of calcium (r=0.09, p=0.36). These results are consistent with Kobayashi et al, who also found no relationship between calcium length and stent expansion (r=0.15, p=0.30).[9] Multiple linear regression analysis showed that actual luminal diameter gains, actual luminal CSA gain, arc of calcium, arc of superficial calcium, and maximal balloon pressure were significantly associated with stent expansion by MLA. These results align with Hoffmann et al.[20] Overall, both the present and previous studies indicate that a larger coronary calcium arc is closely linked to reduced stent expansion, as measured by intravascular ultrasound, in Non-ST Elevation Myocardial Infarction patients.

CONCLUSION

This study shows that a larger coronary calcium arc is significantly associated with reduced stent expansion in NSTEMI patients. A moderate negative correlation between calcium arc and stent expansion was observed. Coronary calcium may serve as an independent predictor of severe CAD in NSTEMI. Stent placement in calcified lesions under high-pressure balloon inflation and IVUS guidance results in fewer clinical events. However, calcified lesions lead to smaller final lumen diameters, less acute lumen gain, and more eccentric expansion.

Recommendations

Adjunctive ablative techniques may improve outcomes in heavily calcified lesions. Further large-scale, randomized trials are needed to confirm these findings.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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