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Original Research

A Comparison of Percutaneous Coronary Intervention Outcomes for Bifurcation Lesions Between Patients With Chronic Coronary Artery Disease and Acute Coronary Syndrome: Analysis of a Multicenter Registry

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Abstract

Background: Percutaneous coronary intervention (PCI) for bifurcation lesions in patients with acute coronary syndrome (ACS) is technically challenging, yet data comparing outcomes with those in patients with chronic coronary disease (CCD) are limited. Thus, this study aimed to compare procedural and long-term clinical outcomes of bifurcation PCI between ACS and CCD patients. **Methods:** A total of 2133 patients were included (1289 with CCD and 844 with ACS). Covariate-balancing propensity score weighting was employed to adjust for baseline differences. The primary outcome was major adverse cardiac events (MACE), defined as a composite of death, non-fatal myocardial infarction (MI), and repeat revascularization (PCI or coronary artery bypass grafting (CABG)). **Results:** Overall, patients with CCD had a higher burden of established atherosclerotic disease and more frequent prior cardiovascular events and revascularization. Cerebrovascular disease, atrial fibrillation, and peripheral artery disease were also more prevalent among patients with CCD. After weighting, procedural success was similar between groups (93% vs 95%; $p = 0.4$), although proximal optimization was used less frequently in ACS (7.0% vs 11%; $p = 0.017$). In the ST-segment elevation myocardial infarction subgroup (n = 253), procedural success was lower (90% vs 95%; $p = 0.009$), and side branch flow disturbance was more common (11% vs 7.4%; $p = 0.045$). Over a median follow-up of 4.1 years, ACS was associated with a higher risk of MACE after adjustment (adjusted hazard ratio (aHR) 1.41, 95% confidence interval (CI) 1.07–1.87), driven primarily by a higher rate of recurrent MI (aHR 2.4, 95% CI 1.42–4.05). Independent predictors of MACE included diabetes, cerebrovascular disease, anemia, and peripheral artery disease. **Conclusions:** Bifurcation PCI in ACS patients is associated with a higher long-term risk of MACE, predominantly due to recurrent MI, despite similar procedural success rates. **The Study Registration:** The study has been registered on: https://www.ClinicalTrials.gov (registration number: NCT03450577; registration link: https://clinicaltrials.gov/study/NCT03450577).

Keywords: STEMI; percutaneous coronary intervention; coronary bifurcation; acute coronary syndrome

1. Introduction

Bifurcation lesions of coronary arteries are a common clinical finding in patients with both chronic coronary disease (CCD) and its acute forms [1,2]. According to research data, in patients with acute coronary syndrome (ACS), the frequency of detecting bifurcations as an "infarct-related" lesion can reach 26% [3,4]. Percutaneous coronary intervention (PCI) for such lesions in ACS is a significantly more complex task compared to elective intervention [5]. This procedure combines risks due to both the severity of the patient's acute condition and the anatomical complexity of the bifurcation lesion itself. Due to the emergency nature of these procedures, they are frequently conducted in the presence of unstable hemodynamics, and bifurcation culprit lesions typically contain a substantial amount of thrombotic material. These factors significantly increase the risk of periprocedural complications, such as acute occlusion of the side branch (SB) due to displacement of unstable atheromatous masses or the development of the no-reflow phenomenon [6,7]. Despite the abundance of works dedicated to bifurcation stenting in general, studies specifically evaluating treatment outcomes in patients with ACS are insufficient. This work aims to fill this gap and evaluate procedural and long-term clinical outcomes depending on the clinical form of coronary heart disease.

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2. Materials and Methods

2.1 Study Design and Population

The International Bifurcation Study (IBS) is a multicenter, real-world registry of consecutive patients undergoing PCI for coronary bifurcation lesions (NCT03450577). Between August 2017 and September 2023, consecutive eligible patients treated at participating high-volume centers were enrolled. For the present analysis, we included patients with available 12-month clinical follow-up, yielding a total of 2133 patients: 1289 patients treated for CCD and 844 patients presenting with ACS. Patients with unsuccessful recanalization of chronic total occlusions (CTO) were excluded from analysis. We performed an additional exploratory subgroup analysis comparing patients presenting with ST-segment elevation myocardial infarction (STEMI) versus patients without STEMI.

Baseline demographics, clinical characteristics, angiographic findings, and procedural details were collected retrospectively from site records, while clinical outcomes during follow-up were recorded prospectively.

2.2 Percutaneous Coronary Intervention Procedure

Coronary interventions were performed in accordance with contemporary guideline recommendations at the time of each procedure. Before PCI, patients received loading doses of aspirin (300 mg) and a P2Y12 inhibitor (clopidogrel 300–600 mg, prasugrel 60 mg, or ticagrelor 180 mg), unless already on antiplatelet therapy. Periprocedural anticoagulation was provided with unfractionated heparin (100 U/kg). According to the local treatment protocols, all patients presenting with non-ST-elevation myocardial infarction (NSTEMI) received P2Y12 inhibitor pretreatment before coronary angiography.

The choice of procedural strategy, including the stenting approach, use of proximal optimization technique, performance of final kissing balloon inflation, vascular access, stent type, and the use of intravascular imaging and/or invasive physiologic assessment, was left to the operator's discretion.

2.3 Data Collection

All patient-related information, including demographics, medications, laboratory findings, angiographic characteristics, procedural details, and outcomes, was collected using a web-based REDCap system.

2.4 Follow-Up

Follow-up was performed either by direct telephone contact with the patient or during an in-person hospital visit.

2.5 Outcomes and Definitions

A bifurcation lesion was defined as a coronary stenosis adjacent to and/or involving an adequate-sized SB with the lesion located ≤4 mm from the point of bifurcation [8].

Bifurcation lesions were classified according to the Medina classification [9] and divided into three segments for quantitative coronary angiography (QCA): proximal main branch (MB), distal MB, and SB. Reference vessel diameter (RVD) and lesion length were measured for each segment.

The primary clinical outcome was major adverse cardiac events (MACE), defined as a composite of death, nonfatal myocardial infarction (MI), and repeat revascularization (PCI or coronary artery bypass grafting (CABG)).

Target lesion revascularization (TLR) was defined as repeat PCI of the target lesion or coronary artery bypass grafting of the target vessel performed for restenosis or other complications of the target lesion [10].

Target vessel revascularization (TVR) was defined as any repeat PCI or surgical bypass of any segment of the target vessel, including the target lesion.

Death was considered cardiac unless an unequivocal non-cardiac cause was established.

MI was defined according to the Fourth Universal Definition of Myocardial Infarction [11].

Troponin levels were measured in all patients presenting with ACS. In patients with CCD, troponin was measured selectively, only in the following situations: (1) acute onset of ischemic symptoms during or after the procedure; (2) new electrocardiographic changes suggestive of acute ischemia; or (3) SB flow impairment after MB stenting.

Technical success was defined as residual stenosis <30% with Thrombolysis in Myocardial Infarction (TIMI) 3 flow at the end of the procedure and was assessed separately for the MB and SB.

Procedural success was defined as technical success in both MB and SB without any in-hospital serious adverse event, including death, MI, urgent repeat revascularization, or pericardiocentesis. Coronary dissections were graded according to the National Heart, Lung, and Blood Institute classification [12].

ACS was defined as an acute clinical presentation consistent with acute myocardial ischemia/infarction and comprised STEMI and non-ST-segment elevation ACS, including NSTEMI and unstable angina.

CCD was defined as established coronary artery disease in a non-acute setting, including patients with prior MI and/or prior coronary revascularization, or those with stable angina and/or documented myocardial ischemia, in the absence of an index ACS presentation.

Disturbance in SB flow was defined as angiographic evidence of impaired flow in the side branch (SB) after stent implantation, compared with baseline. Specifically, this included:

- a reduction in TIMI flow grade in the SB (e.g., from TIMI 3 to TIMI 2/1/0), and/or

- visually sluggish SB flow without a formal TIMI downgrade (i.e., TIMI 3 with delayed opacification/slow washout compared with baseline).

2.6 Statistical Analysis

Statistical analyses were performed in R version 4.0.2 (R Foundation for Statistical Computing Vienna, Austria). Continuous variables are presented as means with standard deviations, and categorical variables as counts and percentages. Missing data were addressed with multiple imputation, generating five imputed datasets. The original (pre-imputation) data were analyzed first, followed by separate analyses of each imputed dataset with results pooled across imputations.

To address initial imbalance between study groups, Covariate Balancing Propensity Score weighting was applied using the WeightIt package (version 1.7.0). The weighting model included covariates associated with the grouping variable (ACS): age, ejection fraction (EF), weight, height, sex, hypertension, diabetes mellitus, dyslipidemia, prior MI, prior PCI, prior CABG, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), anemia, atrial fibrillation, concomitant oral anticoagulant use, chronic kidney disease, peripheral arterial disease, history of cancer, and anatomical descriptors including angle, proximal diameter, distal diameter, side diameter, bifurcation location, trifurcation, calcium, thrombosis, chronic total occlusion bifurcation, Medina class, vascular access site, and complete revascularization.

The target estimand was defined as the average treatment effect. Balance was assessed using standardized mean differences, with a threshold of less than 10% considered acceptable. Balance between weighted groups was visually assessed via histograms, density plots, and love plots.

Adjusted survival (Kaplan-Meier) curves were generated using the adjustedCurves package. Multivariable Cox proportional hazards models were employed to identify predictors of MACE. Confidence interval for weighted estimates were obtained via bootstrap resampling.

Procedural endpoints were analyzed using Pearson's chi-squared test for categorical variables and Welch's two-sample *t*-test for continuous variables, as appropriate. Long-term clinical outcomes were evaluated using Cox proportional hazards models, reporting hazard ratios (HRs) with 95% confidence interval (CI), with the non-STEMI group as the reference category. Outcome definitions were consistent with those used in the main analysis.

3. Results

3.1 Baseline Characteristics

A total of 2133 patients were included in the analysis, with 1289 patients in the CCD group and 844 in the ACS group. Among patients with ACS, 253 had STEMI, 210 had non–ST-elevation MI, and 381 had unstable angina. Age was comparable between groups, whereas the proportion of male patients was lower in the ACS group (Table 1). The prevalence of hypertension, diabetes mellitus, dyslipidemia, chronic obstructive pulmonary disease, and anemia was similar in both groups.

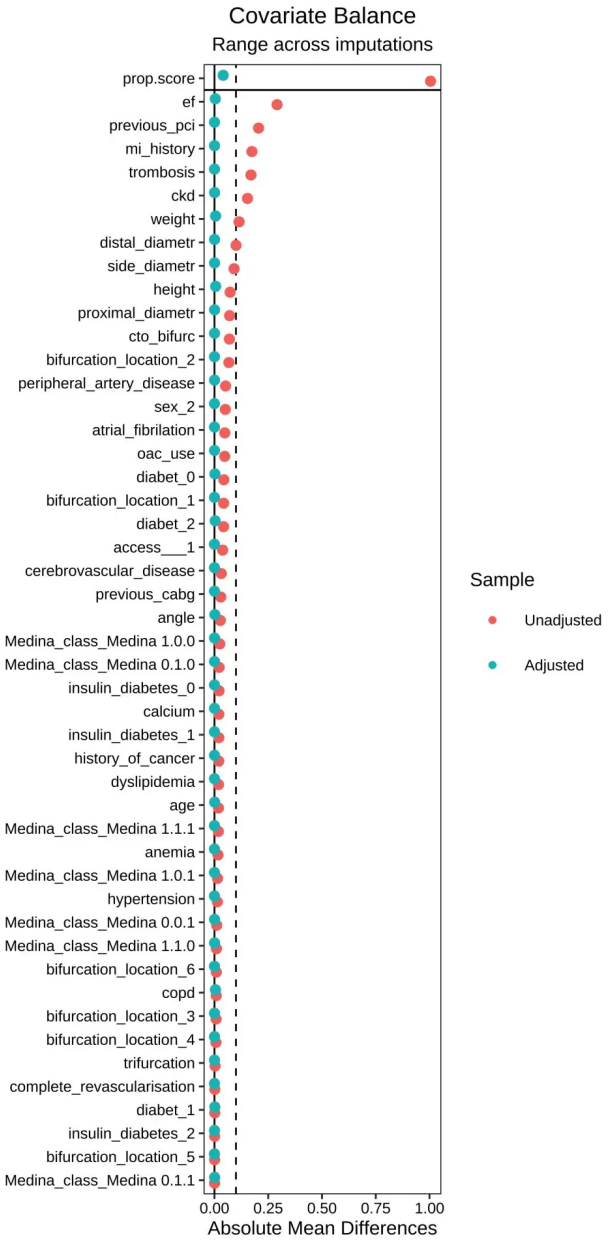


Fig. 1. Covariate balance. Range across imputations.

Overall, patients with CCD had a higher burden of established atherosclerotic disease and more frequent prior cardiovascular events and revascularization. Accordingly, prior MI, previous PCI, and prior CABG were more common in CCD. Cerebrovascular disease, atrial fibrillation, oral anticoagulant use, and peripheral artery disease were also more prevalent among patients with CCD. In contrast, chronic kidney disease was more frequent in the ACS group, and left ventricular ejection fraction was lower compared with CCD. A history of cancer showed a borderline difference between groups.

Table 1. Demographic and clinical characteristics of the study patients.

Variable	Chronic coronary disease (n = 1289)	Acute coronary syndrome (n = 844)	*p*-value
Age	64 (9)	64 (11)	0.669
Male	983 (76%)	601 (71%)	0.010
Hypertension	1213 (94%)	783 (93%)	0.256
Diabetes mellitus	319 (25%)	210 (26%)	0.887
Dyslipidemia	536 (42%)	367 (43%)	0.410
History of MI	667 (52%)	290 (34%)	<0.001
Previous PCI	640 (50%)	246 (29%)	<0.001
Previous CABG	64 (5.0%)	17 (2.0%)	<0.001
Cerebrovascular disease	180 (14%)	91 (11%)	0.036
COPD	82 (6.4%)	46 (5.5%)	0.422
Anemia	58 (4.5%)	52 (6.2%)	0.110
Atrial fibrillation	204 (16%)	93 (11%)	0.002
Patient receives oral anticoagulants	159 (12%)	64 (7.6%)	<0.001
eGFR	76 ± 5.9	74 ± 8.8	<0.001
Peripheral artery disease	134 (10%)	44 (5.2%)	<0.001
History of cancer	78 (6.1%)	34 (4.0%)	0.051
EF, %	57 (11)	54 (10)	<0.001

Abbreviations: PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; EF, ejection fraction; SD, standard deviation.

Note: Continuous variables are reported as mean (standard deviation), and categorical variables as counts and percentages, n (%).

After weighting, covariate balance improved substantially, with no meaningful residual imbalance across prespecified baseline and angiographic variables (Fig. 1).

3.2 Angiographic Characteristics

Angiographic characteristics are summarized in Table 2. Bifurcation angle and proximal MB RVD were comparable between groups. In the ACS cohort, distal MB and SB RVD were slightly larger. The distribution of bifurcation location, the prevalence of trifurcation, calcification, multivessel disease were similar between groups. As expected, angiographic thrombus was substantially more frequent in ACS, whereas CTO bifurcations were more common in CCD. Medina patterns were broadly comparable between groups, and radial access was used more frequently in ACS. PCI for restenosis occurred infrequently and did not differ meaningfully between groups. The utilization of intravascular imaging was similarly low in both the CCD and ACS groups (each <5%, without a meaningful between-group difference).

3.3 Procedural Outcomes

Procedural and angiographic success metrics are shown in the unadjusted and weighted cohorts (Table 3). In the total cohort, procedural success was slightly lower in ACS compared with CCD, whereas after weighting there was no evidence of a between-group difference. Technical success rates in the MB and SB, residual stenosis and residual dissection in both branches, and final TIMI 3 flow in the SB were broadly comparable between groups in both the unadjusted and weighted analyses. Regarding procedural techniques, rates of two-stent strategy and final kissing balloon inflation and stent post dilatation were similar between groups. Proximal optimization was used less frequently in ACS, and this difference remained significant in the weighted cohort. Stent diameter was comparable between groups.

In-hospital MACE occurred infrequently. Although the unadjusted rate was numerically higher in ACS, no meaningful difference was observed between groups after weighting.

3.4 Procedural and In-Hospital Outcomes in STEMI Patients

In the overall cohort, 253 patients presented with STEMI, while the remaining 1880 patients were without STEMI (Table 4). We did attempt to apply weighting methods; however, due to the very pronounced baseline differences between patients with and without STEMI, we were unable to achieve successful covariate balance. Among the 253 patients presenting with STEMI, the timing of PCI from hospital presentation was as follows: 56 patients (22.1%) underwent PCI within 6 hours; 33 patients (13%) within 6 to 12 hours; 34 patients (13.5%) within 12 to 24 hours; 63

Table 2. Baseline angiographic characteristics of the study group.

Variable		Chronic coronary disease (n = 1289)	Acute coronary syndrome (n = 844)	*p*-value
Bifurcation angle, °		58 (23)	57 (24)	0.525
MB proximal RVD, mm		3.37 (0.62)	3.41 (0.66)	0.111
MB distal RVD, mm		2.88 (0.47)	2.92 (0.46)	**0.024**
SB RVD, mm		2.60 (0.54)	2.64 (0.53)	**0.040**
Lesion length, mm		51 (26)	53 (24)	0.214
Bifurcation location	Left main	330 (26%)	180 (21%)	0.732
	LAD/DA	555 (43%)	420 (50%)	
	LCX/OM	242 (19%)	152 (18%)	
	RCA bifurcation	122 (9.5%)	74 (8.8%)	
	LAD/septal	21 (1.6%)	13 (1.5%)	
	Other	19 (1.5%)	5 (0.6%)	
Trifurcation		59 (4.6%)	36 (4.3%)	0.815
Calcification		283 (22%)	168 (20%)	0.280
Thrombosis		7 (0.5%)	148 (18%)	**<0.001**
CTO bifurcation		143 (11%)	35 (4.1%)	**<0.001**
Medina	1,0,0 (%)	257 (20%)	147 (18%)	0.312
	1,1,0 (%)	233 (18%)	160 (19%)	
	1,1,1 (%)	123 (9.6%)	96 (11%)	
	0,1,1 (%)	106 (8.3%)	70 (8.3%)	
	0,0,1 (%)	135 (11%)	79 (9.4%)	
	0,1,0 (%)	355 (28%)	251 (30%)	
	1,0,1 (%)	75 (5.8%)	37 (4.4%)	
Radial access		1168 (91%)	797 (94%)	**0.002**
Multivessel disease		682 (53%)	463 (55%)	0.385
PCI for restenosis		22 (1.7%)	21 (2.5%)	0.309

Abbreviations: CTO, chronic total occlusion; DA, diagonal artery; LAD, left anterior descending artery; RCA, right coronary artery; LCX, left circumflex artery; MB, main branch; OM, obtuse marginal branch; SB, side branch; PCI, percutaneous coronary interventions; SD, standard deviation; RVD, reference vessel diameter.

Note: Continuous variables are reported as mean (standard deviation), and categorical variables as counts and percentages, n (%). Bold values indicate statistical significance ($p < 0.05$).

patients (24.9%) within 24 hours to 7 days; and 67 patients (26.5%) underwent PCI between 7 and 30 days after presentation.

Technical success was slightly lower in STEMI (93% vs 96%; $p = 0.021$), and procedural success was also reduced (90% vs 95%; $p = 0.009$). Disturbance of SB flow occurred more frequently in patients with STEMI (11% vs 7.4%; $p = 0.045$). Both final kissing balloon inflation (31% vs 42%; $p = 0.001$) and proximal optimization (21% vs 28%; $p = 0.008$) were performed less often in the STEMI group. The use of a one-stent technique was numerically higher in STEMI (93% vs 90%), without a statistically significant difference ($p = 0.079$). Residual stenosis and residual dissection rates in both branches were comparable between groups. In-hospital MACE was infrequent and did not differ significantly (4.3% vs 2.4%; $p = 0.11$).

3.5 Long-Term Outcomes

The median follow-up duration was 1504 (interquartile range 1269 to 1801) days. During long-term follow-up, ACS was associated with a higher risk of MACE compared with CCD (adjusted hazard ratio (aHR) 1.41, 95% CI 1.065–1.866; $p = 0.009$). Consistently, the weighted Kaplan–Meier curves for adjusted MACE-free survival showed an early and persistent separation between groups, with lower event-free survival in ACS over time (Fig. 2).

Among individual endpoints, ACS at presentation was associated with a higher hazard of follow-up MI after the index procedure (aHR 2.4, 95% CI 1.421–4.053; $p = 0.001$) and TLR (aHR 1.761, 95% CI 1.183–2.623; $p = 0.006$), consistent with the unadjusted analysis (HR 2.418, 95% CI 1.528–3.829; $p < 0.001$) and (HR 1.534, 95% CI 1.087–2.165; $p = 0.015$) (Table 5). Cardiac death (HR 1.734, 95% CI 1.128–2.667; $p = 0.012$) was higher in the unadjusted analysis, but the association was attenuated after adjustment (aHR 1.54, 95% CI 0.921–2.574; $p = 0.103$). TVR showed a nonsignificant trend toward higher risk in ACS after adjustment (aHR 1.914, 95% CI 0.994–3.658; $p = 0.052$).

Table 3. Procedural characteristics and in-hospital outcomes.

Variable	Total cohort			Adjusted estimates		
	Chronic coronary disease (n = 1289)	Acute coronary syndrome (n = 844)	*p*-value	OR/RD	95% CI	*p*-value
Procedural success	1223 (95%)	780 (93%)	**0.042**	0.85	0.56–1.28	0.431
MB technical success	1245 (97%)	803 (95%)	0.191	1.00	0.61–1.64	0.850
SB technical success	992 (78%)	620 (74%)	0.071	0.92	0.69–1.23	0.640
Residual stenosis in MB	26 (19)	25 (19)	0.741	0.61	0.24–1.55	0.296
Residual stenosis in SB	48 (30)	49 (30)	0.802	0.50	0.22–1.12	0.093
Residual dissection in MB	17 (1.3%)	8 (1.0%)	0.571	0.63	0.26–1.58	0.305
Residual dissection in SB	38 (2.9%)	23 (2.7%)	0.873	0.49	0.23–1.07	0.075
TIMI 3 flow in SB	1225 (95.2%)	806 (95.4%)	0.769	1.45	0.55–3.8	0.501
Two-stent technique	139 (11%)	70 (8%)	0.213	0.75	0.54–1.06	0.107
Final kissing-dilation	554 (44%)	291 (35%)	**0.001**	0.79	0.54–1.14	0.239
Stent postdilation	379 (30%)	244 (29%)	0.864	0.90	0.71–1.15	0.417
Proximal optimization	147 (11%)	59 (7.0%)	**0.001**	0.61	0.41–0.92	**0.017**
Stent diameter	3.23 (0.51)	3.27 (0.52)	0.067	–0.01	–0.07–0.05	0.821
Stent length	24 (8)	24 (8)	0.279	1.80	–2.5–6.1	0.437
Stent number	1.25 (0.5)	1.24 (0.5)	0.805	0	–0.05–0.05	0.892
Complete revascularization	637 (49%)	410 (49%)	0.731	1.00	0.79–1.26	0.875
In-Hospital MACE	29 (2.2%)	27 (3.2%)	0.226	1.10	0.61–1.99	0.731

Abbreviations: MB, main branch; SB, side branch; MACE, major adverse cardivascular events; TIMI, thrombolysis in myocardial infarction; CI, confidence interval; OR, odds ratio; RD, risk difference.

Note: Bold values indicate statistical significance ($p < 0.05$).

Table 4. Procedural and in-hospital characteristics (patients with STEMI vs patients without STEMI).

Variable	Without STEMI (N = 1880)	STEMI (N = 253)	*p*-value
MB technical success	1812 (96)	236 (93)	**0.021**
SB technical success	1425 (76)	187 (74)	0.543
Residual stenosis in MB	26.4 (19.7)	25.6 (16)	0.867
Residual stenosis in SB	48.9 (29.7)	47.6 (28)	0.630
Residual dissection in MB	21 (1.1)	4 (1.6)	0.709
Residual dissection in SB	55 (2.9)	6 (2.4)	0.791
Procedural success (%)	1775 (95)	228 (90)	**0.009**
Disturbance of blood flow in SB after stent implantation	136 (7.4)	28 (11)	**0.045**
Final kissing balloon inflation	768 (42)	77 (31)	**0.001**
One-stent technique	1688 (90)	236 (93)	0.079
Proximal optimization	534 (28)	52 (21)	**0.008**
In-hospital MACE	45 (2.4)	11 (4.3)	0.110

Abbreviations: MACE, major adverse cardiac events; MB, main branch; SB, side branch; STEMI, ST-segment elevation myocardial infarction.

Note: Categorical variables are presented as n (%). Continuous variables are presented as mean ± SD. Bold values indicate statistical significance ($p < 0.05$).

3.6 Long-Term Outcomes in STEMI Patients

During follow-up, patients presenting with STEMI did not have a higher risk of MACE than patients without STEMI (HR 0.966, 95% CI 0.709–1.316; $p = 0.825$) (Table 6). In contrast, STEMI was associated with significantly higher risks of all-cause death (HR 2.134, 95% CI 1.370–3.322; $p < 0.001$) and cardiac death (HR 3.021, 95% CI 1.808–5.048; $p < 0.001$). No statistically significant differences were observed for TVR (HR 0.856; $p = 0.764$), TLR (HR 0.439; $p = 0.421$), or MI (HR 1.572; $p = 0.187$).

3.7 Multivariable Analysis

In the multivariable Cox model, older age and lower ejection fraction were independently associated with a higher risk of MACE. Female sex was associated with a lower hazard of MACE. Diabetes mellitus, cerebrovascular disease, anemia, and peripheral artery disease remained significant independent predictors of MACE in the multivariable model (Table 7).

In the weighted adjusted analysis, the direction and magnitude of associations were largely consistent. Female

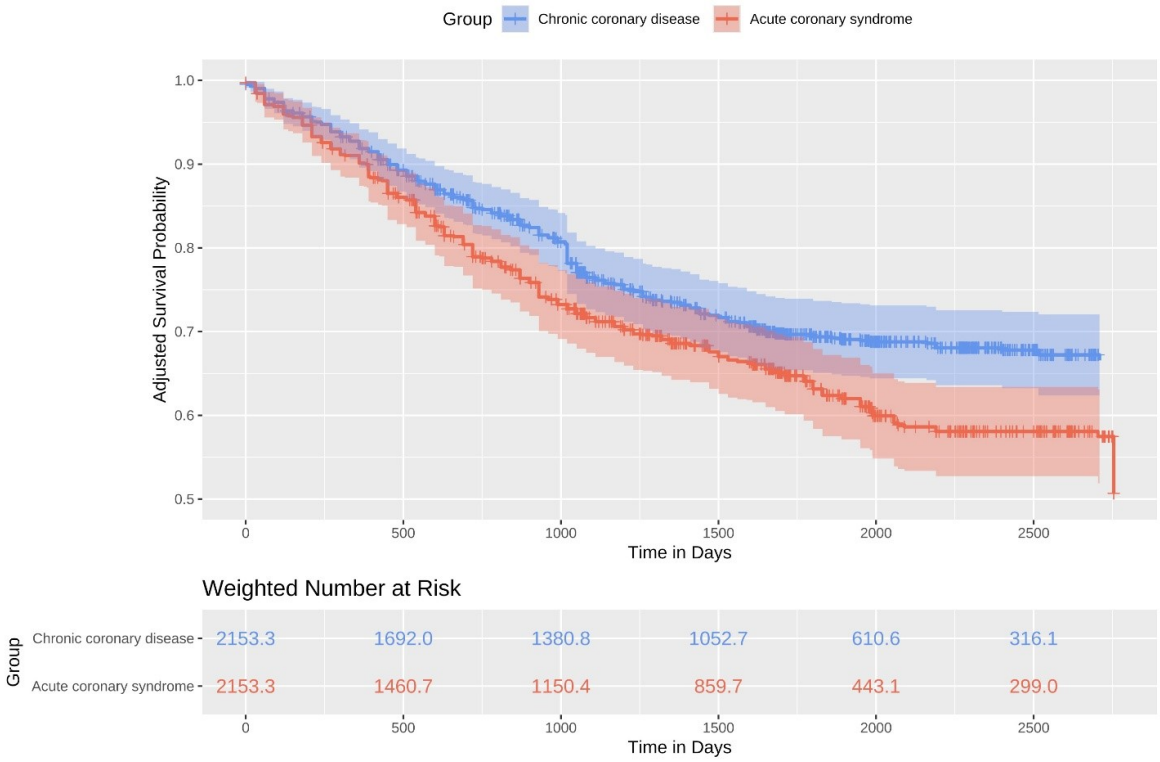


Fig. 2. Weighted Kaplan–Meier curves for adjusted MACE-free survival in CCD vs ACS.

Table 5. Long-term outcomes (ACS vs CCD).

Characteristic		Cumulative incidence			Unadjusted estimates			Adjusted estimates		
		365 Days	1096 Days	1826 Days	HR	95% CI	*p*-value	HR	95% CI	*p* -value
MACE	CCD	7.0 (5.7, 8.6)	9.2 (7.6, 11)	15 (13, 18)	—	—		—	—	
	ACS	9.5 (7.5, 12)	13 (11, 16)	20 (16, 23)	1.34	1.054–1.704	**0.017**	1.41	1.065, 1.866	**0.009**
All-cause death	CCD	4.3 (3.3, 5.6)	4.8 (3.7, 6.3)	7.2 (5.8, 9.0)	—	—		—	—	
	ACS	5.6 (4.1, 7.6)	6.7 (5.1, 9.0)	8.8 (6.7, 11)	1.224	0.871–1.722	0.244	1.08	0.721, 1.619	0.721
Cardiac death	CCD	2.3 (1.6, 3.3)	2.5 (1.7, 3.5)	3.8 (2.8, 5.2)	—	—		—	—	
	ACS	4.2 (2.9, 6.1)	4.6 (3.2, 6.5)	6.5 (4.7, 8.9)	1.734	1.128–2.667	**0.012**	1.54	0.921, 2.574	0.103
TVR	CCD	1.3 (0.7, 2.1)	2.2 (1.5, 3.4)	2.9 (2.0, 4.3)	—	—		—	—	
	ACS	2.1 (1.2, 3.6)	2.5 (1.5, 4.2)	4.4 (2.8, 6.9)	1.626	0.937–2.820	0.084	1.914	0.994, 3.658	0.052
TLR	CCD	2.4 (1.7, 3.5)	3.9 (2.9, 5.3)	7.7 (6.1, 9.8)	—	—		—	—	
	ACS	3.8 (2.6, 5.7)	6.4 (4.7, 8.8)	11 (8.8, 15)	1.534	1.087–2.165	**0.015**	1.761	1.183, 2.623	**0.006**
MI	CCD	1.2 (0.7, 2.0)	1.7 (1.1, 2.7)	3.2 (2.2, 4.6)	—	—		—	—	
	ACS	3.5 (2.3, 5.3)	5.0 (3.6, 7.2)	8.0 (5.9, 11)	2.418	1.528–3.829	**<0.001**	2.4	1.421, 4.053	**0.001**

Abbreviations: ACS, Acute coronary syndrome; CCD, Chronic coronary disease; CI, Confidence Interval; HR, Hazard Ratio; MACE, major adverse cardiac events; TVR, target vessel revascularization; TLR, target lesion revascularization; MI, myocardial infarction.

Note: Bold values indicate statistical significance ($p < 0.05$).

sex remained associated with a reduced risk (HR 0.59, 95% CI 0.45–0.77; $p < 0.001$), whereas diabetes mellitus (HR 1.33, 95% CI 1.04–1.72; $p = 0.026$), cerebrovascular disease (HR 1.70, 95% CI 1.30–2.22; $p < 0.001$), anemia (HR 1.67, 95% CI 1.20–2.32; $p = 0.003$), and peripheral artery disease (HR 1.44, 95% CI 1.04–1.98; $p = 0.028$) were associated with increased risk. Age showed a borderline association after weighting (HR 1.01, 95% CI 1.00–1.02; $p = 0.070$), while ejection fraction remained inversely associated with MACE (HR 0.99, 95% CI 0.98–1.00; $p = 0.037$). Complete revascularization was associated with a lower risk in the multivariable model, but this association was not significant after weighting.

Table 6. Long-term outcomes (patients with STEMI vs patients without STEMI).

Outcome	HR	95% CI	*p*-value
MACE	0.966	0.709–1.316	0.825
All-cause death	2.134	1.370–3.322	<0.001
Cardiac death	3.021	1.808–5.048	<0.001
TVR	0.856	0.310–2.363	0.764
TLR	0.439	0.059–3.257	0.421
MI	1.572	0.804–3.074	0.187

Abbreviations: CI, Confidence Interval; HR, Hazard Ratio; MACE, major adverse cardiac events; TVR, target vessel revascularization; TLR, target lesion revascularization; MI, myocardial infarction.

Clinical presentation as ACS was not statistically significant in the univariate model (HR = 1.20; 95% CI 0.97–1.48; $p = 0.087$) and is therefore not included as an independent predictor based on this analysis.

4. Discussion

The main findings of this study are as follows: patients with ACS exhibited a higher incidence of MACE in the long-term period, primarily due to a higher rate of recurrent MI. Clinical factors (ejection fraction, age, anemia, cerebrovascular disease, peripheral arterial disease, diabetes mellitus) were independent predictors of MACE. In contrast to patients with CCD, ACS patients were found to be more 'preserved', with a lower incidence of prior MI, peripheral artery disease, cerebrovascular disease and previous revascularization procedures. For patients with STEMI, there was a lower frequency of technical success in the MB. Additionally, a reduced application of optimization techniques and a higher incidence of blood flow disturbance in the SB following stent implantation were observed. Despite having significantly fewer comorbidities, patients with STEMI experienced a higher rate of cardiac mortality during long-term follow-up.

The treatment of bifurcation lesions in the context of ACS poses a significant challenge for interventional cardiologists. Studies have shown that stenting of bifurcation lesions in patients with ACS is associated with greater technical complexity compared to non-bifurcation lesions [5,13]. However, these studies did not demonstrate a negative impact of bifurcation lesions on prognosis [5,13]. Although the consensus documents of the European Bifurcation Club acknowledge bifurcation stenting in ACS, particularly with STEMI, as a unique clinical situation, most recommendations for selecting stenting and optimization techniques are oriented towards CCD and are not always suitable for emergency interventions [1,14]. This is due to the insufficient number of studies evaluating approaches to bifurcation stenting in this category of patients. In our study, patients with ACS more often experienced MACE in the long-term period due to higher rates of recurrent MI. Furthermore, these patients showed a tendency towards more frequent cardiac mortality and repeat revascularization of the target vessel. This aligns with the results of the Sang Song et al. study [15], where bifurcation stenting in NSTEMI patients was associated with a higher frequency of MACE at 2 years compared to patients with stable coronary artery disease (7.3 vs 5.2 $p = 0.042$). However, in another registry, Zabrze–Opole, which compared the results of bifurcation stenting in patients with and without MI, there was no difference in MACE-TLF in the long-term period [16]. In our study true bifurcation lesions (Medina 1.1.1, 0.1.1, 1.0.1) constituted less than 25% of our cohort, which is somewhat lower than in some dedicated bifurcation registries [17]. This explains the low rate of two-stent techniques (8–11%) observed in our study. However, our registry is an all-comer, real-world study reflecting routine clinical practice, where simpler Medina patterns predominate. Moreover, provisional-stenting is currently the gold-standard strategy for all types of bifurcation lesions, including true bifurcation lesions, and is particularly recommended in patients with ACS according to the European Bifurcation Club consensus documents [14]. In our study, regression analysis did not identify either the Medina class or the stenting technique as independent predictors of long-term MACE. This finding suggests that clinical presentation drives outcomes independently of anatomical bifurcation complexity and technique selection.

Patients with STEMI constitute a special group. In these patients, the "infarct-related" artery almost always contains a large, fresh thrombus [18]. This significantly complicates the stenting procedure and increases the risks of periprocedural complications. Moreover, additional manipulations with the guidewire and balloon catheters can also increase the risk of thrombotic embolization, which limits the possibilities for optimizing the implanted stent [19]. Our study noted that optimization techniques (kissing dilatation and proximal optimization) were less frequently applied in STEMI patients. This is likely due to the desire to shorten the procedure time and reduce the risks of thrombotic mass dislocation. At the same time, data from the COBIS II registry show that in STEMI patients, the application of a two-stent strategy (a more complex technique) was associated with worse long-term outcomes, mainly due to an increased frequency of stent thrombosis and target lesion revascularization [17]. This indirectly confirms that in ACS, a simpler and faster "provisional" stenting strategy for the SB, even with a suboptimal angiographic result, may be preferable to complex and lengthy interventions. In this study, there was a trend towards more frequent use of provisional stenting in patients presenting MI (93% vs 90%), but this difference did not reach statistical significance ($p = 0.3$). In this context, the limited use of adjunctive techniques aimed at procedural optimization appears clinically justified. This consideration extends not only to complex

Table 7. Multivariate analysis of MACE predictors: unadjusted and adjusted (weighted) models.

Characteristic	Unadjusted HR (95% CI)	*p*-value	Adjusted HR (95% CI)	*p*-value
Age, per 1-year increase	1.02 (1.01–1.03)	<0.001	1.01 (1.00–1.02)	0.070
Left ventricular ejection fraction, per 1% increase	0.99 (0.98–0.99)	0.001	0.99 (0.98–1.00)	0.037
Female sex	0.71 (0.57–0.88)	0.002	0.59 (0.45–0.77)	<0.001
Diabetes mellitus	1.38 (1.14–1.67)	<0.001	1.33 (1.04–1.72)	0.026
Cerebrovascular disease	1.67 (1.34–2.09)	<0.001	1.70 (1.30–2.22)	<0.001
Anemia	1.72 (1.25–2.35)	<0.001	1.67 (1.20–2.32)	0.003
Peripheral artery disease	1.68 (1.30–2.17)	<0.001	1.44 (1.04–1.98)	0.028
Complete revascularization	0.82 (0.69–0.97)	0.025	0.88 (0.71–1.09)	0.200

Abbreviations: CI, confidence interval; HR, hazard ratio.

Note: Multivariable HRs were derived from a Cox proportional hazards model. Weighted adjusted HRs were derived from a weighted Cox model. Continuous variables are reported per unit increase.

stenting strategies but also to the use of intravascular imaging modalities.

At the current stage of interventional cardiology, considerable attention is devoted to the use of adjunctive intravascular imaging modalities during PCI, given their potential to optimize stent implantation and enhance procedural safety. In our study, however, the utilization rate of these techniques was relatively low, which likely reflects the persistent operator dependence in decision-making, including the choice to employ additional imaging, as well as the clinical and anatomical complexity of individual cases.

It is noteworthy that recent randomized trials have not demonstrated a clear benefit of the routine use of intravascular imaging in certain patient subsets. In particular, in the setting of PCI for unprotected left main coronary artery disease where lesions are frequently bifurcation in nature as well as in complex high-risk PCI, no significant improvement in clinical outcomes was observed with intravascular ultrasound (IVUS) guidance compared with angiography alone [20]. Furthermore, the randomized study by Lee et al. [21] demonstrated that IVUS-guided PCI did not reduce the incidence of adverse events, defined as target lesion failure, compared with quantitative coronary angiography over a 12-month follow-up period. Thus, despite the theoretical and technological potential benefits of intravascular imaging, their routine use particularly in patients with bifurcation lesions remains a matter of ongoing debate. Our findings are consistent with the contemporary body of evidence and underscore the need for further studies aimed at refining clinical indications and identifying patient subgroups most likely to derive benefit from these technologies.

In our study, the frequency of all-cause mortality and cardiovascular mortality was higher in the STEMI group. Nevertheless, the overall frequency of adverse events was comparable between the compared groups. These data are consistent with the results of a large study by Thrane et al. [22], which compared the long-term outcomes of 18,818 STEMI patients with the general population. It was shown that for patients who underwent PCI and survived the first 90 days, 10-year mortality was only 2% higher than in the control group. A probable explanation for this is that STEMI patients, despite the acute condition, initially had fewer concomitant risk factors such as previous revascularization surgeries, a history of prior MI, peripheral artery diseases, arterial hypertension, and a history of oncological diseases. Although clinical factors were independent predictors of adverse events. It should be noted that the differences in clinical characteristics between STEMI and non-STEMI patients were so significant that their complete statistical balancing proved almost impossible, which could have influenced the comparison results. Therefore, these findings should be interpreted as purely hypothesis-generating and exploratory.

The procedural outcomes related to the SB in STEMI patients are particularly noteworthy. In our study, these patients more often experienced disturbance of blood flow in the SB after stent implantation in the main vessel. It is important to note that SB protection was applied in only 41% of patients, which likely reflects the operators' desire to maximize simplification and speed of the procedure in an emergency situation. Despite frequent initial disturbance of blood flow, the final result (final TIMI flow in the SB) did not statistically significantly differ between the groups. Our observations are consistent with the results of the multicenter STEMI-BIF registry, which specifically studied the active SB protection strategy in STEMI patients [23]. This registry demonstrated that the use of more complex techniques aimed at protecting the SB, although it improved immediate angiographic results (leading to less residual stenosis and reducing the need for additional interventions on the SB), did not translate into improved long-term clinical outcomes. Similar results were demonstrated in the study by Tigen et al. [24]. The authors showed that attempting to preserve the SB is advisable for achieving a better procedural outcome, but only if this branch is large (≥2 mm) and originates directly from the lesion site [24]. However, since this approach does not necessarily translate into improved in-hospital clinical outcomes and may be associated with certain procedural risks, a conservative main-vessel-oriented strategy may be reasonable in selected cases.

Anemia is a common comorbidity among patients undergoing PCI and has consistently been associated with adverse cardiovascular outcomes. A recent meta-analysis by Kwok et al. [25] demonstrated that anemia significantly increases the risks of mortality, MI, bleeding, and major adverse cardiovascular events following PCI.

Although the statistical effect of anemia was similar in ACS and CCD patients, the underlying biological mechanisms may differ. In ACS, anemia likely aggravates the acute imbalance between myocardial oxygen supply and demand during active ischemia, potentially contributing to larger infarct size, impaired ventricular recovery, and adverse remodeling. In contrast, in CCD, chronic anemia may promote sustained myocardial oxygen deprivation, compensatory increases in cardiac workload, and progressive ventricular remodeling, thereby increasing long-term susceptibility to ischemic events.

Thus, while the mechanisms may differ between acute and chronic coronary syndromes, our findings suggest that anemia remains an important independent predictor of long-term MACE across the entire spectrum of coronary artery disease.

Beyond procedural factors, long-term outcomes after bifurcation PCI are critically dependent on adherence to dual antiplatelet therapy (DAPT) and secondary prevention measures. Notably, in our study, ACS patients had a significantly higher risk of recurrent MI during follow-up (aHR 2.4), which may be partly attributable to suboptimal medication adherence. In this context, digital health interventions represent a promising strategy. Recent evidence indicates that mobile applications and smart-device-based follow-up tools can improve medication adherence in high-risk cardiovascular patients. In a meta-analysis by Şaylık et al. [26], which evaluated the effect of digital health interventions on follow-up outcomes in 7657 patients with ACS, the authors demonstrated that, compared with standard care, the use of mobile devices significantly improved treatment adherence by 69% and reduced rates of rehospitalization by 55% and cardiac mortality by 49%. These findings underscore the potential of digital health tools to enhance secondary prevention. Future studies should explore whether integrating such technologies into routine care after bifurcation PCI could mitigate the excess risk of recurrent MI observed in ACS patients.

Limitations

Our findings should be interpreted in the context of several limitations. First, this is a non-randomized, observational registry study. Despite the use of propensity score weighting to adjust for measured confounders, the potential for residual confounding due to unmeasured variables cannot be eliminated. Second, the ACS group itself is heterogeneous, encompassing STEMI, NSTEMI, and unstable angina. While we performed an exploratory subgroup analysis of STEMI versus non-STEMI, the limited sample size of the STEMI subgroup (n = 253) may have reduced the statistical power to detect differences in some long-term outcomes, such as MI and TLR. Third, the use of intravascular imaging was remarkably low (<5%) in both groups. This reflects real-world practice in many centers during the study period but limits our ability to assess the mechanisms of stent failure or the quality of stent optimization, which could influence long-term outcomes like stent thrombosis and restenosis. Fourth, despite the use of standardized angiographic definitions across participating centers, the lack of an independent central Core-laboratory for adjudication of lesion characteristics and procedural angiographic outcomes may have introduced measurement bias. Finally, follow-up was not available in all registry patients.

5. Conclusions

Bifurcation stenting in ACS was associated with a higher incidence of MACE at follow-up, predominantly due to recurrent MI. Patients with STEMI exhibited higher cardiac mortality compared to patients without STEMI.

Abbreviations

ACS, Acute coronary syndrome; CABG, Coronary artery bypass grafting; CCD, Chronic coronary disease; CI, Confidence interval; CKD, Chronic kidney disease; COPD, Chronic obstructive pulmonary disease; CTO, Chronic total occlusion; DA, Diagonal artery; DAPT, Dual antiplatelet therapy; EF, Ejection fraction; HR, Hazard ratio; IQR, Interquartile range; IVUS, Intravascular ultrasound; LAD, Left anterior descending artery; LCX, Left circumflex artery; MACE, Major adverse cardiac events; MB, Main branch; MI, Myocardial infarction; NSTEMI, Non–ST-elevation myocardial infarction; OM, Obtuse marginal branch; OR, Odds ratio; PCI, Percutaneous coronary intervention; QCA, Quantitative coronary angiography; RCA, Right coronary artery; RVD, Reference vessel diameter; SB, Side branch; SD, Standard deviation; STEMI, ST-segment elevation myocardial infarction; TIMI, Thrombolysis in Myocardial Infarction; TLR, Target lesion revascularization; TVR, Target vessel revascularization.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

DK: contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. IBes: contributed to the design and implementation of the research, data curation and to the writing of the manuscript. MK: contributed to the image analysis, to the analysis of the results and to the writing of the manuscript. SS: contributed to the patient recruit-

ment, to the analysis of the results and to the writing of the manuscript. ABad: contributed to the patient recruitment, to the image analysis and the writing of the manuscript. SM: contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. ABar: contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. RU: contributed to the data collection, image analysis and interpretation, preparation of figures and writing of the manuscript. IBel: contributed to the data collection, image analysis and interpretation, and writing of the manuscript. MM: contributed tothe preparation of tables, to the analysis of the results and to the writing of the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki. The research protocol was approved by the Ethics Committee of Meshalkin National Medical Research Center (Ethic Approval Number: № 13/1 from 16.09.2016). The ethics committee granted a waiver of informed consent as the study involved the analysis of existing anonymized data and posed minimal risk to the participants.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Pan M, Lassen JF, Burzotta F, Ojeda S, Albiero R, Lefèvre T, et al. The 17th expert consensus document of the European Bifurcation Club - techniques to preserve access to the side branch during stepwise provisional stenting. EuroIntervention. 2023; 19: 26–36. https://doi.org/10.4244/EIJ-D-23-00124

[2] Aedma SK, Naik A, Kanmanthareddy A. Coronary Bifurcation Stenting: Review of Current Techniques and Evidence. Current Cardiology Reviews. 2023; 19: e060422203185. https://doi.org/10.2174/1573403X18666220406113517

[3] Abdel-Hakim DE, Garot P, Champagne S, Maklady F, el-Hawary A, Dubois-Randé JL, et al. Impact of bifurcation lesions on clinical outcome and prognosis of primary angioplasty in acute myocardial infarction. EuroIntervention. 2008; 4: 93–98. https://doi.org/10.4244/eijv4i1a16

[4] Kanei Y, Nakra NC, Liou M, Singh J, Fox JT, Kwan TW. The importance of bifurcation lesions in patients undergoing percutaneous coronary interventions in ST-segment elevation myocardial infarction. Cardiovascular Revascularization Medicine. 2013; 14: 81–83. https://doi.org/10.1016/j.carrev.2012.12.002

[5] Salinas P, Mejía-Rentería H, Herrera-Nogueira R, Jiménez-Quevedo P, Nombela-Franco L, Núñez-Gil IJ, et al. Bifurcation Culprit Lesions in ST-segment Elevation Myocardial Infarction: Procedural Success and 5-year Outcome Compared With Nonbifurcation Lesions. Revista Española de Cardiología (English Edition). 2018; 71: 801–810. https://doi.org/10.1016/j.rec.2017.06.022 (In English, Spanish)

[6] Leesar MA, Hakeem A, Azarnoush K, Thuesen L. Coronary bifurcation lesions: Present status and future perspectives. International Journal of Cardiology. 2015; 187: 48–57. https://doi.org/10.1016/j.ijcard.2015.03.183

[7] Dou K, Zhang D, Xu B, Yang Y, Yin D, Qiao S, et al. An angiographic tool for risk prediction of side branch occlusion in coronary bifurcation intervention: the RESOLVE score system (Risk prEdiction of Side branch OccLusion in coronary bifurcation interVEntion). JACC. Cardiovascular Interventions. 2015; 8: 39–46. https://doi.org/10.1016/j.jcin.2014.08.011

[8] Lunardi M, Louvard Y, Lefèvre T, Stankovic G, Burzotta F, Kassab GS, et al. Definitions and Standardized Endpoints for Treatment of Coronary Bifurcations. Journal of the American College of Cardiology. 2022; 80: 63–88. https://doi.org/10.1016/j.jacc.2022.04.024

[9] Medina A, Suárez de Lezo J, Pan M. A new classification of coronary bifurcation lesions. Revista Española de Cardiología (English Edition). 2006; 59: 183.

[10] Garcia-Garcia HM, McFadden EP, Farb A, Mehran R, Stone GW, Spertus J, et al. Standardized End Point Definitions for Coronary Intervention Trials: The Academic Research Consortium-2 Consensus Document. Circulation. 2018; 137: 2635–2650. https://doi.org/10.1161/CIRCULATIONAHA.117.029289

[11] Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth universal definition of myocardial infarction (2018). European Heart Journal. 2019; 40: 237–269. https://doi.org/10.1093/eurheartj/ehy462

[12] Huber MS, Mooney JF, Madison J, Mooney MR. Use of a morphologic classification to predict clinical outcome after dissection from coronary angioplasty. The American Journal of Cardiology. 1991; 68: 467–471. https://doi.org/10.1016/0002-9149(91)90780-o

[13] Dudek D, Mehran R, Dziewierz A, Brener SJ, Rakowski T, Brzezinski M, et al. Impact of bifurcation target lesion on angiographic, electrocardiographic, and clinical outcomes of patients undergoing primary percutaneous coronary intervention (from the Harmonizing Outcomes With Revascularization and Stents in Acute Myocardial Infarction [HORIZONS-AMI] trial). EuroIntervention. 2013; 9: 817–823. https://doi.org/10.4244/EIJV9I7A135

[14] Burzotta F, Louvard Y, Lassen JF, Lefèvre T, Finet G, Collet C, et al. Percutaneous coronary intervention for bifurcation coronary lesions using optimised angiographic guidance: the 18th consensus document from the European Bifurcation Club. EuroIntervention. 2024; 20: e915–e926. https://doi.org/10.4244/EIJ-D-24-00160

[15] Sang Song P, Ryeol Ryu D, Choi SH, Yang JH, Song YB, Hahn JY, et al. Impact of acute coronary syndrome classification and procedural technique on clinical outcomes in patients with coronary bifurcation lesions treated with drug-eluting stents. Clinical Cardiology. 2012; 35: 610–618. https://doi.org/10.1002/clc.22020

[16] Milejski W, Sacha J, Feusette P, Cisowski M, Muzyk P, Tomasik A, et al. Real-Life Outcomes of Coronary Bifurcation Stenting in Acute Myocardial Infarction (Zabrze-Opole Registry). Journal of Cardiovascular Development and Disease. 2021; 8: 155. https://doi.org/10.3390/jcdd8110155

[17] Choi KH, Song YB, Jeong JO, Park TK, Lee JM, Yang JH, et

al. Treatment Strategy for STEMI With Bifurcation Culprit Lesion Undergoing Primary PCI: The COBIS II Registry. Revista Española de Cardiología (English Edition). 2018; 71: 811–819. https://doi.org/10.1016/j.rec.2018.01.002 (In English, Spanish)

[18] Kraler S, Mueller C, Libby P, Bhatt DL. Acute coronary syndromes: mechanisms, challenges, and new opportunities. European Heart Journal. 2025; 46: 2866–2889. https://doi.org/10.1093/eurheartj/ehaf289

[19] Okamura A, Ito H, Iwakura K, Kurotobi T, Koyama Y, Date M, et al. Clinical implications of distal embolization during coronary interventional procedures in patients with acute myocardial infarction: quantitative study with Doppler guidewire. JACC. Cardiovascular Interventions. 2008; 1: 268–276. https://doi.org/10.1016/j.jcin.2008.03.015

[20] Testa L, De la Torre Hernandez JM, De Maria GL, Jones DA, Piñon-Esteban P, Campo G, et al. IVUS-Guided versus Angiography-Guided PCI in Unprotected Left Main Coronary Disease. The New England Journal of Medicine. 2026; 394: 2189–2199. https://doi.org/10.1056/NEJMoa2600440

[21] Lee PH, Hong SJ, Kim HS, Yoon YW, Lee JY, Oh SJ, et al. Quantitative Coronary Angiography vs Intravascular Ultrasonography to Guide Drug-Eluting Stent Implantation: A Randomized Clinical Trial. JAMA Cardiology. 2024; 9: 428–435. https://doi.org/10.1001/jamacardio.2024.0059

[22] Thrane PG, Olesen KKW, Thim T, Gyldenkerne C, Hansen MK, Stødkilde-Jørgensen N, et al. 10-Year Mortality After ST-Segment Elevation Myocardial Infarction Compared to the General Population. Journal of the American College of Cardiology. 2024; 83: 2615–2625. https://doi.org/10.1016/j.jacc.2024.04.025

[23] Güner A, Serin E, Zehir R, Şimşek B, Öz A, Çizgici AY, et al. Active Side-Branch Protection Strategy for Culprit Bifurcation Lesion in STEMI Patients: The Multicenter STEMI-BIF Registry. Catheterization and Cardiovascular Interventions. 2025; 106: 2647–2660. https://doi.org/10.1002/ccd.70107

[24] Tigen K, Dogan Z, Sunbul M, Gurel E, Cincin A, Kanar B, et al. "Main Vessel-Oriented" Treatment Strategy Versus "Open Side Branch" Treatment Strategy in Acute Coronary Syndrome Patients With Culprit Bifurcation Lesions. The American Journal of Cardiology. 2023; 204: 339–344. https://doi.org/10.1016/j.amjcard.2023.07.132

[25] Kwok CS, Tiong D, Pradhan A, Andreou AY, Nolan J, Bertrand OF, et al. Meta-Analysis of the Prognostic Impact of Anemia in Patients Undergoing Percutaneous Coronary Intervention. The American Journal of Cardiology. 2016; 118: 610–620. https://doi.org/10.1016/j.amjcard.2016.05.059

[26] Şaylık F, Çınar T, Hayıroğlu Mİ, Tekkeşin Aİ. Digital Health Interventions in Patient Management Following Acute Coronary Syndrome: A Meta-Analysis of the Literature. Anatolian Journal of Cardiology. 2023; 27: 2–9. https://doi.org/10.14744/AnatolJCardiol.2022.2254