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OUTCOMES OF THE JAILED BALLOON TECHNIQUE FOR CORONARY BIFURCATION LESIONS IN ACUTE CORONARY SYNDROME

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ABSTRACT

Coronary bifurcation lesions in patients with acute coronary syndrome are associated with a high risk of side branch occlusion after main vessel stenting. The jailed balloon technique is a simple strategy for side branch protection; however, real-world data remain limited. This prospective descriptive interventional study without a control group aimed to evaluate the outcomes of the jailed balloon technique and identify factors associated with side branch occlusion following percutaneous coronary intervention in acute coronary syndrome. This study included 31 patients with true bifurcation lesions undergoing percutaneous coronary intervention using the jailed balloon technique at Interventional Cardiology Unit, Intensive Care and Toxicology Department, Tay Ninh General Hospital from May 2025 to June 2026. The incidence of side branch occlusion was 22.6%. Post-procedural residual stenosis is <30% in the main vessel was achieved in 96.8% of cases, and no patient required side branch stenting. Procedural complications were infrequent (3.22% side branch dissection). Acute heart failure occurred more frequently in patients with side branch occlusion ($p<0.05$). Multivariable logistic regression identified longer side branch lesion length as an independent predictor of side branch occlusion (adjusted OR 1.30, 95% CI 1.02–1.55; $p = 0.031$). In conclusion, the jailed balloon technique in coronary bifurcation intervention among patients with acute coronary syndrome demonstrates high technical success and a low complication rate. Side branch lesion length is an independent predictor of post-procedural side branch occlusion.

Keywords: bifurcation lesion; jailed balloon technique; side branch occlusion; acute coronary syndrome.

INTRODUCTION

Among patients with acute coronary syndrome (ACS), the presence of unstable atherosclerotic plaques increases the risk of side branch occlusion following stenting of the main vessel. A provisional one-stent strategy with side branch protection is recommended in most bifurcation lesions. The jailed balloon technique (JBT) is a simple method that helps maintain side branch access and reduce the risk of side branch occlusion after percutaneous coronary intervention (PCI) (Wu*et al.,* 2025). However, data on the efficacy of this technique and the factors associated with side branch occlusion in ACS patients in Vietnam remain limited. Therefore, we conducted this study to evaluate the outcomes of JBT and to identify several factors associated with side branch occlusion after intervention in ACS patients with bifurcation lesions.

MATERIALS AND METHODS

Materials: Thirty-one consecutive patients with ACS were enrolled who underwent coronary angiography and/or percutaneous coronary intervention (PCI) with jailed balloon technique at Interventional Cardiology Unit, Intensive Care and Toxicology Department, Tay Ninh General Hospital, from May 2025 to June 2026.

Inclusion criteria: Patients were eligible for inclusion if they met all of the following criteria: (1) Patients were diagnosed with acute coronary syndrome (ACS) according to "the Fourth Universal Definition of Myocardial Infarction" (2018) (Thygesen *et al.,* 2018); (2) Patients underwent coronary angiography and/or percutaneous coronary intervention (PCI); (3) and bifurcation lesions requiring side branch protection were defined by the following criteria: the presence of a main vessel (MV) stenosis ≥70% (except for left main coronary artery (LM) lesions ≥50%). A side branch requiring protection was defined as a side branch vessel diameter ≥2.0 mm, side branch lesion length ≥5 mm, and ostial side branch stenosis ≥50%.

Exclusion criteria: Patients were excluded if they met any of the following criteria: (1) Patients diagnosed with acute coronary syndrome (ACS) who underwent coronary angiography but in whom complete coronary anatomical assessment could not be performed due to severe clinical conditions, such as acute pulmonary edema or cardiogenic shock requiring early termination of the procedure; (2) For the selection of bifurcation lesions requiring side branch protection, patients with hemodynamically significant coronary stenosis is associated with bifurcation lesions were included; however, those with unfavorable coronary anatomy-such as severe calcification or complex bifurcation angles that made guide wire crossing difficult; and (3) Patients who refused to participate in the study.

Study design and sampling method: The final study population comprised 31 patients. The study used convenience sampling, selecting all patients who met the inclusion criteria and did not meet the exclusion criteria during the study period.

Data collection and clinical measurements:

Clinical and angiographic data were prospectively collected using a standardized case report form. Baseline demographic and clinical characteristics included age, sex, family history of cardiovascular disease, smoking status, previous stroke, peripheral artery disease, hypertension, diabetes mellitus, dyslipidemia, and chronic kidney

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disease. Angiographic characteristics of coronary bifurcation lesions were evaluated before PCI. Lesion location was classified as left main coronary artery bifurcation or non-left main bifurcation involving the left anterior descending artery/diagonal branch, left circumflex artery/obtuse marginal branch, or right coronary artery/posterior descending artery/posterolateral ventricular branch. Bifurcation lesions were classified according to the Medina classification as 1,1,1;1,0,1; or 0,1,1. Plaque distribution was categorized as being located on the same side as or opposite to the side branch. The bifurcation angle was measured and categorized as <70° or ≥70°. Coronary calcification was graded as noneor moderate. The degree of luminal stenosis, vessel diameter, and lesion length of both the main vessel and side branch were recorded.

Procedural and angiographic outcomes of the jailed balloon technique were assessed, including post-procedural TIMI flow grade, residual stenosis, side branch occlusion, and the need for side branch stenting. TIMI flow was categorized as TIMI 3 or TIMI <3. Procedural complications included jailed balloon entrapment, balloon rupture, side branch dissection, and conversion to side branch stenting. The V-RESOLVE score was calculated to estimate the risk of side branch occlusion.

In-hospital clinical outcomes included death, acute heart failure, stroke, post-procedural myocardial infarction, and target lesion revascularization. The association between side branch occlusion and potential clinical, angiographic, and procedural risk factors was subsequently analyzed.

Statistical analysis: Data were analyzed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro–Wilk test and are presented as mean ± standard deviation (SD) or median (interquartile range [IQR]), as appropriate. Categorical variables are presented as frequencies and percentages. Comparisons between patients with and without side branch occlusion were performed using the independent-samples t test or the Mann–Whitney *U* test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Variables with a p value <0.10 in the univariate analysis or considered clinically relevant were entered into a multivariable logistic regression model to identify independent predictors of side branch occlusion. Results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). A two-sided p value <0.05 was considered statistically significant.

Ethical considerations: The study protocol was approved by the Institutional Review Board and the Ethics Committee of Can Tho University of Medicine and Pharmacy (approval number: 25.221.HV/PCT-HĐĐĐ).Before inclusion in the study, subjects or their authorized guardians were fully briefed on the research objectives and protocols. Participation was contingent upon obtaining prior written informed consent. All personal metrics were anonymized and used solely within the scope of this investigation.

RESULTS

Baseline characteristics

A total of 31 patients with acute coronary syndrome and coronary bifurcation lesions who underwent percutaneous coronary intervention using the jailed balloon technique were included in the analysis. The baseline demographic and clinical characteristics of the study population are summarized in Table 1.

Table 1. Baseline characteristics of the study participants (n=31)

Characteristics	Side branch occlusion (n=7)	No side branch occlusion (n=24)	Overall (n=31)	p
Age, years	66±10.76	59.7±9.49	61.4±10.02	0.68
Male sex	4 (57.1)	14 (58.3)	18 (58.1)	1.00
Smoking history	1 (14.3)	8 (33.3)	9 (29.0)	0.64
Stroke	0 (0.0)	1 (4.2)	1 (3.2)	1.00
Peripheral arterial disease	0 (0.0)	0 (0.0)	0 (0.0)	NA
Family history	0 (0.0)	1 (4.2)	1 (3.2)	1.00
Hypertension	7 (100)	24 (100)	31 (100)	NA
Diabetes mellitus	3 (42.9)	12 (50.0)	15 (48.4)	1.00
Dyslipidemia	7 (100)	23 (95.8)	30 (96.8)	1.00
Chronic kidney disease	1 (14.3)	1 (4.2)	2 (6.5)	0.41

The mean age of the participants was 61.4 ± 10.02 years, and 58.1% were male. Hypertension and dyslipidemia were the most prevalent cardiovascular risk factors, affecting 100% and 96.8% of patients, respectively, whereas peripheral arterial disease was not observed. No significant differences in baseline demographic or clinical characteristics were found between patients with and without side branch occlusion (p > 0.05).

Table 2. Characteristics of bifurcation lesions

Characteristics			Side branch occlusion (n=7)	No side branch occlusion (n=24)	Overall (n=31)	p
Medina classification	0,1,1		2 (28.6)	10 (41.7)	12 (38.7)	0.11
	1,0,1		0 (0.0)	7 (29.2)	7 (22.6)	
	1,1,1		5 (71.4)	7 (29.2)	12 (38.7)	
Location of bifurcation lesions	LM		0 (0.0)	4 (16.7)	4 (12.9)	0.56
	LAD-D		6 (85.7)	14 (58.3)	20 (64.5)	
	LCX/OM		1 (14.3)	2 (8.3)	3 (9.7)	
	RCA/PDA		0 (0.0)	4 (16.7)	4 (12.9)	
Main vessel characteristics	Severity of stenosis(%)		82.14±12.86	83.5±12.84	82.63±12.46	0.66
	TIMI	<3	3 (42.9)	8 (33.3)	11 (35.5)	0.68
		3	4 (57.1)	16 (66.7)	20 (64.5)	
Atherosclerotic plaque	Side-branch side		6 (85.7)	10 (41.7)	16 (51.6)	0.08
	Opposite to side branch		1 (14.3)	14 (58.3)	15 (48.4)	
Side branch characteristics	Diameter, mm		4.75±6.73	2.37±0.31	2.93±3.24	0.66
	Length, mm		15.86±10.75	6.3±3.18	8.53±6.96	0.005
	Severity of stenosis (%)		78.57±9.00	74.58±11.79	75±11.06	0.43
	TIMI	<3	4 (57.1)	6 (25.0)	10 (32.3)	0.172
		3	3 (42.9)	18 (75.0)	21 (67.7)	
Bifurcation angle	<70		3 (42.9)	12 (50.0)	15 (48.4)	1.00
	≥70		4 (57.1)	12 (50.0)	16 (51.6)	
Severity of calcification	Moderate		1 (25)	2 (75)	3 (9.6)	0.26
	None		6 (21.4)	22 (78.6)	28 (90.4)	
Mean V-RESOLVE score			22.29±6.6	16.79±7.73	17.63±7.55	0.11

Medina 0,1,1 and 1,1,1 classifications were the most frequently observed (38.7%). Regarding the anatomical location, the most common bifurcation lesion site was the LAD-D (64.5%). The mean MV severity of stenosis was 82.63 ± 12.46%, with baseline TIMI 3 flow being predominant (64.5%). Similarly, the mean SB severity of stenosis was approximately 75 ± 11.06%, also predominantly with TIMI 3 flow (64.5%). The mean SB lesion length was 8.53 ±6.96 mm; notably, the SB occlusion group exhibited significantly longer lesion lengths compared to the non-occlusion group ($p< 0.05$). A bifurcation angle ≥70° was observed in 51.6% of patients. In terms of plaque distribution, the atherosclerotic plaque was more commonly located on the side-branch side than on the opposite side (51.6%). Moderate calcification was observed in 9.6% of cases. The mean V-RESOLVE score was 17.63 ± 7.55.

Outcomes of side branch protection with jailedballoon

Table 3. Outcomes of side branch protection with jailed balloon

Characteristics		Side branch occlusion (n=7)	No side branch occlusion (n=24)	Overall (n=31)	p
Main vessel					
TIMI	<3	3 (42.9)	8 (33.3)	11 (35.5)	0.68
	3	4 (57.1)	16 (66.7)	20 (64.5)	
Residual stenosis	<30	6 (85.7)	24 (100)	30 (96.8)	0.23
	≥30	1 (14.3)	0 (0.0)	1 (3.2)	
Procedural complications					
Side branch dissection		0 (0.0)	1 (4.2)	1 (3.2)	1.00
Balloon entrapment		0 (0.0)	0 (0.0)	0 (0.0)	
Balloon rupture		0 (0.0)	0 (0.0)	0 (0.0)	
Requirement for side branch stenting		0 (0.0)	0 (0.0)	0 (0.0)	
In-hospital adverse events					
Post-PCI acute heart failure		4 (57.1)	3 (12.5)	7 (22.6)	0.03
Stroke		0 (0.0)	0 (0.0)	0 (0.0)	
Post-PCI myocardial infarction		0 (0.0)	0 (0.0)	0 (0.0)	
Target lesion revascularization		0 (0.0)	0 (0.0)	0 (0.0)	
Death		1 (14.3)	0 (0.0)	1 (3.2)	0.23

Regarding procedural and angiographic outcomes, TIMI 3 flow in the main vessel (MV) was achieved in 64.5% of cases, while an acceptable residual stenosis was observed in 96.8% of patients. In terms of complications, side branch (SB) dissection occurred at a rate of 3.2%. The incidence of acute heart failure was 22.6%, which was significantly more prevalent in the patient group that experienced SB occlusion following MV stenting ($p< 0.05$).

Predictive factors for side branch occlusion

Table 4. Predictive factors for side branch occlusion

Characteristics	Univariate analysis			Multivariate analysis		
	B	p	OR (95% CI)	B	p	OR (95% CI)
Medina						
0,1,1	1	0.66				
1,0,1	-18.6	0.99	0			
1,1,1	2.1	0.37	8.30 (0.08-834.4)			
Calcification						
None	1					
Moderate	0.7	0.87	2.00 (0.00-14450.8)			
SB length	0.26	**0.038**	1.30 (1.01-1.65)	0.23	**0.031**	1.3 (1.02-1.55)
V-RESOLVE	0.11	0.24	1.12 (0.93-1.35)			

Univariate logistic regression analysis identified side branch (SB) length as a significant predictor of side branch occlusion (OR = 1.30, 95% CI: 1.01–1.65, p = 0.038). After adjustment for potential confounders, SB length remained an independent predictor in the multivariable model (adjusted OR = 1.30, 95% CI: 1.02–1.55, p = 0.031). In contrast, Medina classification, severity of calcification, and the V-RESOLVE score were not significantly associated with side branch occlusion (p > 0.05).

DISCUSSION

The mean age was 61.4 ± 10.02, in which males predominated and hypertension was the most common underlying disease, consistent with the epidemiological characteristics of acute coronary syndrome (ACS). However, there was no difference (p> 0.05), reflecting that systemic risk factors do not directly determine the mechanism of side branch occlusion. This result is similar to the JACC study (Hahn et al., 2013). Bifurcation lesions were mainly Medina 0,1,1 and 1,1,1. The lesion location was mainly concentrated at LAD-D (64.5%) (p> 0.05). The JACC study showed that the lesion location was significantly related to the risk of side branch occlusion (Hahn*et al.,* 2013). This difference is due to the small sample size and rare alternative lesion locations, which reduced the comparative power between subgroups. In addition, the uniform application of the Jailed Balloon Technique (JBT) strategy may reduce the influence of anatomical location on side branch occlusion events. The mean MV stenosis is degree was 82.63 ± 12.46%, with the majority achieving TIMI 3 before intervention (64.5%) (p> 0.05), showing that the severity of the main vessel is not related to the risk of side branch occlusion. The side branch occlusion group had significantly longer side branch lesion lengths than the non-occlusion group (15.86 ± 10.75 mm vs. 6.30 ± 3.18 mm; p = 0.005). This is consistent with the "carina shift" and "plaque shift" mechanisms, in which extensive lesions or side branches with significant size are easily affected after main vessel stenting. The distribution of plaque on the same side as the side branch tended to be related to side branch occlusion, suggesting the role of plaque burden at the carina region. However, the angle, calcification degree, and pre-interventional side branch TIMI did not show any difference. This result is similar to the study of Park et al. (2014). The mean V-RESOLVE score was higher in the side branch occlusion group (22.29 ± 6.6 compared to 16.79 ± 7.73; p= 0.11), showing the trend of the predictive value of this score in assessing the risk of side branch occlusion.

Post-intervention, the majority of patients achieved TIMI 3 in the main vessel (64.5%) and the rate of residual stenosis is <30% was very high (96.8%), reflecting the good revascularization efficacy of this strategy. No difference was recorded between the side branch occlusion and non-occlusion groups (p> 0.05), showing that the main vessel revascularization efficacy was relatively uniform between the groups. The rate of procedural complications was low: side branch dissection safety of the JBT technique. However, post-procedural acute heart failure event occurred at a rate of 22.6% and was significantly higher in the side branch occlusion group (p= 0.03). This result suggests that although main vessel revascularization achieved requirements in terms of imaging, side branch occlusion can still adversely affect hemodynamics and left ventricular function in the early post-interventional phase. Compared with the study by Wu et al. (2025), a significantly higher rate of myocardial infarction (14.6% compared to 3.5%; p= 0.003) was recorded in the side branch occlusion group. This difference may be related to the larger sample size in the study by Wu et al., which helped detect rare events. In addition, the relatively uniform JBT strategy in our study may have limited the severity of acute myocardial ischemia after side branch occlusion.

Side branch lesion length was an independent factor associated with side branch occlusion after main vessel stenting (adjusted OR = 1.30; 95% CI: 1.02–1.55; p = 0.031). This result emphasizes the role of side branch morphological characteristics in the "plaque shift" and "carina shift" mechanisms, as prolonged lesions increase the risk of hemodynamic impairment after intervention. In the Frontiers study, the independent predictors of side branch occlusion were: true bifurcation lesions, the MV/SB diameter ratio, and the V-RESOLVE score (Wu*et al.,* 2025). In contrast, in our study, V-RESOLVE and the Medina classification were not significant. This difference can be explained by several factors. Firstly, the sample size of our study was relatively small, which reduced the ability to detect concomitant risk factors in the multivariate model. Secondly, there were differences in the study population and interventional strategies. Our study focused on the JBT technique; therefore, the direct morphological characteristics of the side branch may play a more prominent role. Meanwhile, the Frontiers study analyzed a larger population with many complex anatomical morphological variables, allowing factors such as V-RESOLVE and the MV/SB ratio to clearly demonstrate their prognostic value. Overall, the two studies do not contradict but rather complement each other. While the Frontiers study emphasizes the role of global morphological factors of the bifurcation area, our results suggest that in the context of the jailed balloon technique, the characteristics of the side branch - especially the lesion length - may play a decisive role in the prognosis of side branch occlusion.

CONCLUSION

The jailed balloon technique demonstrates high main vessel revascularization efficacy and a low rate of procedural complications. However, side branch occlusion is associated with an increased risk of post-procedural acute heart failure during the in-hospital stay. Longer side branch lesion length was an independent predictor of side branch occlusion after main vessel stenting. The results emphasize the role of pre-procedural side branch morphological assessment in order to optimize treatment strategies in bifurcation lesions.

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