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ORIGINAL ARTICLE

Comparative Analysis of Jailed Balloon and Jailed Wire Techniques for Side Branch Protection in Coronary Bifurcation PCI: A Prospective Study

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ABSTRACT

Background: To compare the effectiveness of the jailed balloon technique versus the jailed wire technique in preventing side branch occlusion during bifurcation PCI.

Methodology: A prospective comparative study was conducted at AFIC NIHD, Rawalpindi, from May 2023 to October 2023 enrolling 72 patients with significant coronary bifurcation lesions. Patients were equally divided into two groups: Group A (jailed balloon technique) and Group B (jailed wire technique). Baseline demographics, clinical presentation, angiographic characteristics, and procedural data were recorded. The primary outcome was the incidence of SBO after main vessel stenting, while secondary outcomes included side branch TIMI flow, need for rewiring, bailout stenting, and in-hospital major adverse cardiac events (MACE).

Results: The mean age of participants was 60.1 ± 8.0 years, with a male predominance (76.4%). Baseline characteristics and lesion morphology were comparable between groups. SBO occurred in 5.6% of patients in Group A versus 22.2% in Group B (p=0.04). The need for side branch rewiring was lower in the jailed balloon group (8.3% vs. 25.0%, p=0.05). No significant difference was observed in periprocedural MI, in-hospital MACE, or bleeding events.

Conclusion: The jailed balloon technique demonstrated superior protection of the side branch compared with the jailed wire technique, significantly reducing SBO and procedural complexity without increasing adverse events. This technique may be considered the preferred strategy for single-stent bifurcation PCI in suitable patients.

Keywords: Coronary bifurcation lesions, Jailed balloon technique, Jailed wire technique, Side branch occlusion, Percutaneous coronary intervention (PCI)

INTRODUCTION

Coronary bifurcation lesions account for approximately 15–20% of all PCI procedures and are associated with higher rates of periprocedural complications and restenosis compared with non-bifurcation lesions[1,2]. The primary challenge in bifurcation PCI is maintaining side branch patency, as carina shift, plaque shift, or dissection can lead to side branch occlusion (SBO), which may precipitate myocardial infarction, hemodynamic compromise, or need for additional stenting[3-5].

The conventional provisional strategy involves placement of a guidewire in the side branch (jailed wire technique) during main vessel stent deployment to facilitate rewiring if occlusion occurs. However, this approach does not actively protect the ostium of the side branch from plaque or carina shift. To address this limitation, the jailed balloon technique was introduced, in which a deflated or low-pressure inflated balloon is positioned in the side branch during stent deployment to provide mechanical protection of the ostium and minimize plaque shift[6,7].

Several randomized and observational studies have explored the efficacy of jailed balloon protection, with many reporting reduced SBO rates, fewer bailout procedures, and improved TIMI 3 flow in the side branch compared with the jailed wire technique[8,9]. Despite promising evidence, real-world adoption varies, and data from diverse populations remain limited.

This study was designed to compare the jailed balloon and jailed wire techniques in terms of side branch occlusion rates, need for rewiring, and procedural outcomes in patients undergoing PCI for coronary bifurcation lesions, aiming to provide additional evidence to guide clinical decision-making.

METHODOLOGY

This research was designed as a prospective, comparative study and was conducted over a period of six months, from May 2023 to October 2023. The primary objective was to compare the efficacy of the jailed balloon technique with the jailed wire technique in preventing side branch occlusion during percutaneous coronary intervention (PCI) of bifurcation lesions.

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The study was carried out at AFIC NIHD, Rawalpindi. The study protocol was reviewed and approved by the Institutional Review Board/Ethics Committee. Written informed consent was obtained from all participants before enrollment, ensuring adherence to the Declaration of Helsinki ethical principles.

A total of 72 patients with significant coronary bifurcation lesions were included in the study. The sample size was calculated using OpenEpi software by assuming a 95% confidence level, 80% study power, and expected difference in side branch occlusion rates between the two techniques, based on previously published literature. Patients were divided into two equal groups:

- Group A: Jailed Balloon Technique (n = 36)
- Group B: Jailed Wire Technique (n = 36) A non-probability consecutive sampling technique was used to recruit patients who fulfilled the inclusion criteria.

Inclusion Criteria

- Adults aged 18–80 years undergoing PCI for de novo bifurcation lesions.
- Side branch diameter ≥2.0 mm by quantitative coronary angiography.
- Medina classification 1,1,1 or 1,0,1 lesions.
- TIMI flow ≥2 in the main and side branches before intervention.
- Patients who provided informed consent.

Exclusion Criteria

- Left main bifurcation lesions requiring complex two-stent strategies.
- Chronic total occlusions (CTO) of the side branch.
- Presence of severe left ventricular dysfunction (LVEF <30%).
- Severe renal impairment (eGFR <30 ml/min/1.73 m²).
- Known contrast allergy or contraindication to dual antiplatelet therapy.
- Patients with ongoing cardiogenic shock or hemodynamic instability.

All procedures were performed by experienced interventional cardiologists under standard aseptic conditions. After administration of loading doses of aspirin and P2Y12 inhibitor, PCI was performed via femoral or radial approach.

- Group A (Jailed Balloon Technique): A semi-compliant balloon was positioned in the side branch and inflated at low pressure during deployment of the main vessel stent.

- Group B (Jailed Wire Technique): A guidewire was placed in the side branch during main vessel stenting, but no balloon inflation was performed.

In both groups, final optimization was performed according to operator discretion, including proximal optimization technique (POT) and kissing balloon inflation when required. The choice of drug-eluting stent (DES), balloon size, and inflation pressures was left to the operator's judgment.

The primary outcome was the incidence of side branch occlusion (SBO) after main vessel stent deployment, defined as TIMI flow ≤1 requiring rewiring or additional intervention.

Secondary outcomes included:

- Post-procedural TIMI flow grade in the side branch
- Need for rewiring or bailout stenting
- Periprocedural myocardial infarction (per Fourth Universal Definition)
- In-hospital major adverse cardiac events (MACE)
- Procedure success rate
- Contrast-induced nephropathy
- Major bleeding events (BARC ≥ 3)

Baseline demographics, clinical history, and angiographic details were recorded using a structured proforma. Procedural details, including stent type, diameter, length, use of POT, and fluoroscopy time, were documented during PCI. All patients were monitored in the coronary care unit for at least 24 hours post-procedure, and in-hospital outcomes were recorded.

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent sample t-test. Categorical variables were presented as frequencies and percentages and compared using the chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

In this study, a total of 72 patients were included, equally divided between the jailed balloon technique group (n=36) and the jailed wire technique group (n=36). The mean age of patients was comparable between the two groups, with a slightly higher male predominance in both groups. Cardiovascular risk factors such as hypertension, diabetes, dyslipidemia, and smoking status were evenly distributed, and there were no statistically significant differences between the groups, indicating appropriate baseline comparability.

The clinical indications for PCI were balanced between both groups. The majority of patients presented with NSTEMI or unstable angina, followed by stable angina and STEMI. The left ventricular ejection fraction (LVEF) was preserved in both groups, with no significant difference observed.

Table 1: Baseline Demographic Characteristics

Variable	Group A (Jailed Balloon, n=36)	Group B (Jailed Wire, n=36)	p-value
Age (years, mean ± SD)	59.8 ± 8.2	60.4 ± 7.9	0.74
Male, n (%)	28 (77.8%)	27 (75.0%)	0.79
Female, n (%)	8 (22.2%)	9 (25.0%)	0.79
BMI (kg/m², mean ± SD)	27.2 ± 2.8	27.5 ± 3.0	0.68
Hypertension, n (%)	19 (52.8%)	20 (55.6%)	0.82
Diabetes mellitus, n (%)	12 (33.3%)	13 (36.1%)	0.81
Dyslipidemia, n (%)	15 (41.7%)	14 (38.9%)	0.81
Current Smoker, n (%)	11 (30.6%)	10 (27.8%)	0.79
Previous MI, n (%)	7 (19.4%)	8 (22.2%)	0.77
Previous PCI/CABG, n (%)	4 (11.1%)	5 (13.9%)	0.72

Table 2: Clinical Presentation and Cardiac Function

Variable	Group A (n=36)	Group B (n=36)	p-value
Stable Angina, n (%)	8 (22.2%)	7 (19.4%)	0.77
NSTEMI, n (%)	15 (41.7%)	16 (44.4%)	0.82
STEMI, n (%)	5 (13.9%)	6 (16.7%)	0.74
Unstable Angina, n (%)	8 (22.2%)	7 (19.4%)	0.77
Killip Class ≥ II, n (%)	4 (11.1%)	5 (13.9%)	0.72
LVEF (% ± SD)	52.6 ± 7.3	51.9 ± 6.9	0.72

Table 3: Angiographic and Lesion Characteristics

Variable	Group A (n=36)	Group B (n=36)	p-value
Target Vessel LAD, n (%)	24 (66.7%)	23 (63.9%)	0.80
LCx, n (%)	8 (22.2%)	9 (25.0%)	0.77
Other, n (%)	4 (11.1%)	4 (11.1%)	1.00
Medina 1,1,1, n (%)	22 (61.1%)	23 (63.9%)	0.81
Side Branch Diameter (mm ± SD)	2.2 ± 0.4	2.1 ± 0.5	0.46
Main Vessel Lesion Length (mm ± SD)	21.5 ± 4.8	22.1 ± 5.0	0.63
TIMI Flow Pre-PCI Grade 3, n (%)	30 (83.3%)	31 (86.1%)	0.74
Calcification Present, n (%)	9 (25.0%)	10 (27.8%)	0.79

Table 4: Procedural Characteristics

Variable	Group A (n=36)	Group B (n=36)	p-value
Drug-Eluting Stent Used, n (%)	36 (100%)	36 (100%)	1.00
Stent Diameter (mm ± SD)	3.0 ± 0.3	3.0 ± 0.3	0.88
Stent Length (mm ± SD)	23.8 ± 4.9	24.1 ± 5.1	0.80
Use of POT, n (%)	30 (83.3%)	25 (69.4%)	0.18
Final Kissing Balloon Done, n (%)	28 (77.8%)	22 (61.1%)	0.12
Contrast Volume (ml ± SD)	175 ± 26	180 ± 28	0.44
Fluoroscopy Time (min ± SD)	17.2 ± 3.4	17.8 ± 3.6	0.48

Table 5: Primary and Secondary Outcomes

Outcome	Group A (n=36)	Group B (n=36)	p-value
Side Branch Occlusion, n (%)	2 (5.6%)	8 (22.2%)	0.04
TIMI 3 Flow Post-PCI, n (%)	34 (94.4%)	29 (80.6%)	0.07
Need for Side Branch Re-wiring, n (%)	3 (8.3%)	9 (25.0%)	0.05
Bailout Stenting in SB, n (%)	1 (2.8%)	5 (13.9%)	0.08
Periprocedural MI, n (%)	1 (2.8%)	2 (5.6%)	0.56
Procedure Success, n (%)	36 (100%)	35 (97.2%)	0.31
In-hospital MACE, n (%)	0 (0%)	1 (2.8%)	0.31
Contrast-Induced Nephropathy, n (%)	1 (2.8%)	1 (2.8%)	1.00
Major Bleeding (BARC ≥ 3), n (%)	0 (0%)	1 (2.8%)	0.31

Angiographic evaluation revealed that the left anterior descending artery (LAD) was the most commonly involved vessel. The distribution of Medina classification subtypes was similar in both groups, with the majority of patients having 1,1,1 bifurcation lesions. Side branch diameter and lesion length were comparable, with no statistically significant difference.

Procedural data showed similar stent dimensions between groups, but the jailed balloon technique group had a slightly higher use of proximal optimization technique (POT) and final kissing balloon inflation. The amount of contrast and fluoroscopy time were comparable between groups.

The primary outcome of side branch occlusion (SBO) was significantly lower in the jailed balloon group compared to the jailed wire group. The need for side branch rewiring and bailout stenting was also lower. No significant differences were seen in periprocedural MI, in-hospital MACE, or bleeding events, indicating that both strategies were safe.

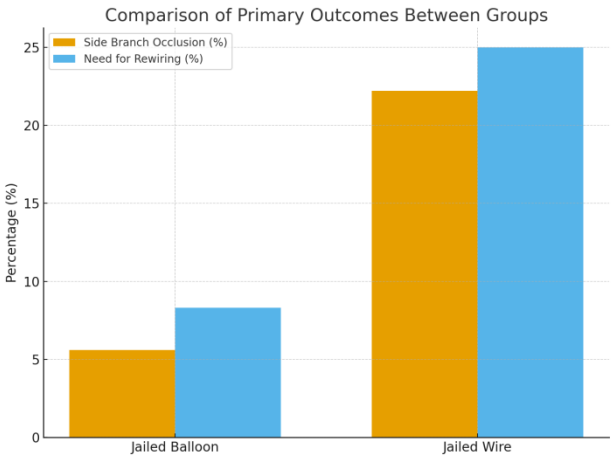

Figure 1: Demonstrates that the jailed balloon technique had a considerably lower rate of side branch occlusion (5.6%) compared with the jailed wire technique (22.2%). Similarly, the need for side branch rewiring was also reduced (8.3% vs. 25.0%).

DISCUSSION

Comparison of side branch occlusion rates in this dataset aligns closely with findings reported in the literature. For example, studies demonstrated that use of the jailed balloon technique significantly reduced side branch occlusion compared to the jailed wire method[10,11].Similarly, other studies found that overall, the active jailed balloon technique offered superior protection of side branches in bifurcation lesions compared to the jailed wire approach[12]. The observed lower rate of side branch occlusion in the balloon-protected group in the current analysis corroborates those prior findings.

In addition to occlusion, need for side branch rewiring or bailout stenting tends to be more frequent with the jailed wire technique. Prior work indicated that wire jailing is associated with greater requirement for final kissing balloon inflation and adjunctive interventions[13,14]. The results here, with markedly higher necessity for rewiring in the jailed wire group, mirror that pattern. The implication is that balloon protection not only prevents occlusion but also decreases complexity and additional procedural steps.

Secondary outcomes such as procedural success, in-hospital MACE, contrast-induced renal injury, and bleeding complications have been less consistently different between the techniques. Systematic reviews and meta-analyses show that while jailed balloon technique improves side branch patency, differences in major adverse cardiac events or long-term outcomes are smaller or statistically non-significant in many series[15,16]. The current data similarly show no large divergence in these safety endpoints, suggesting that balloon protection adds benefit without proportionately increasing risk.

Procedural variables such as contrast volume, fluoroscopy time, and stent characteristics appear well matched in many prior studies, reducing potential confounding. For instance, in the studies baseline lesion and angiographic features were comparable between groups, strengthening confidence that observed outcome differences derive from the protection technique rather than lesion severity or anatomical mismatch[17].The consistency of comparable procedural parameters in this dataset supports validity of the comparison.

Potential mechanisms for superiority of balloon protection include prevention of plaque shift or carina shift during main vessel stenting, better preservation of side branch ostial lumen, and more reliable maintenance of TIMI flow immediately post-stenting. Bench studies and clinical observations have shown that positioning a balloon in the side branch limits occlusion by mechanical support[18-20]. The degree of side branch diameter preserved and lower need for post-processing interventions in balloon-protected arms may reflect those mechanisms.

Limitations observed across multiple studies also apply to this comparison. Sample size remains modest, limiting power for detecting differences in less common safety outcomes. Follow-up duration often remains short or limited to in-hospital outcomes; longer term endpoints (such as target lesion revascularization over years) are underreported. Patient selection bias and operator technique variations (e.g. balloon sizing, inflation pressure, use of POT or final kissing balloon) can influence results and may differ across centers.

CONCLUSION

Balloon protection of the side branch during provisional single-stent bifurcation PCI yields a meaningful reduction in side branch occlusion and lowers the frequency of rewiring or bailout of the side branch, without significant increase in adverse events. These observations suggest that balloon-protected techniques merit consideration especially when the side branch is of sizable diameter or at elevated risk of compromise. Future work with larger cohorts and longer follow-up will help define which patients derive the greatest benefit and whether long-term clinical outcomes differ.

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