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Decoding In-Stent Restenosis: A Single Center Experience

Siva Santhosh Rangan [a++], Abhishek Kasha [a#*], Dhamodaran. K [a#], Immaneni Sathyamurthy [a#], Aishwarya Mahesh Kumar [a#], Prathaban Kuppusamy [a++], Rallapalli Spandana [a++] and Sivaganesh Dhanasekaran [a++]

[a] *Apollo Main Hospital, Chennai, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The current study aims to investigate the underlying mechanisms contributing to the development of in-stent restenosis (ISR), the effectiveness of various treatment approaches, and the role of advanced imaging techniques in its diagnosis and management. The study focuses on providing comprehensive insights to improve patient care and clinical outcomes in ISR cases.
Study Design: Retrospective observational monocentric study.
Place and Duration of Study: Apollo Hospitals, Chennai on 50 patients with ISR from April 2022 to October 2023
Methodology: Patients with prior percutaneous coronary intervention (PCI) presenting with ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI), unstable angina, positive stress tests, or revascularization failure in bare metal stent

[++] *Post graduate;*
[#] *Consultant;*
**Corresponding author: Email: cardio.abhi@gmail.com;*

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(BMS) or drug eluting stent (DES) were included. Exclusions were coronary artery bypass grafting (CABG), non-drug-coated balloons, left main restenosis, thrombus, or early restenosis within three months. The primary outcome, major adverse cardiovascular events (MACE), was a composite of cardiovascular death, target lesion revascularization (TLR), target vessel revascularization (TVR), and myocardial infarction (MI).

Results: Analysis of ISR mechanisms showed stent under-expansion in 48% of cases with stent boost. On imaging Neo-intimal hyperplasia was found in 20%, and neoatherosclerosis in 14% of patients. The imaging group had a significant reduction in MACE. Most patients (78%) received DES, while 22% received Drug coated balloon (DCB), with no significant outcome differences between them. Additionally, ticagrelor or prasugrel use in ISR patients significantly reduced event rates.

Conclusion: Our findings suggest that imaging-guided PCI can significantly reduce the incidence of major adverse cardiac events. Additionally, potent P2Y12 inhibitors like ticagrelor and prasugrel may offer superior outcomes to clopidogrel in ISR patients. While both adequate lesion preparation using ELCA or specialty balloons and understanding the mechanism of ISR using imaging followed by DCB or DES or combining both demonstrated fairly similar outcomes in our study with a slight inclination towards imaging and ELCA for better long term results, further research and large number of studies is needed to assess their relative efficacy in ISR definitively.

Keywords: In-stent restenosis; imaging guided PCI; drug eluting stent; drug coated balloon.

ABBEREVATIONS

BMS : Bare Metal Stent
CCS : Chronic Coronary Syndrome
COPD : Chronic Obstructive Pulmonary Disease
CKD : Chronic Kidney Disease
DES : Drug Eluting Stent
DEB : Drug Eluting Balloon
DM : Diabetes Mellitus
HTN : Hypertension
ELCA : Excimer Laser Coronary Angioplasty
IVL : Intra-Vascular Lithotripsy
ISR : In-Stent Restenosis
IVUS : Intravascular Ultrasound
MACE : Major Adverse Cardiovascular Events
MACCE : Major Adverse Cardiac and Cardiovascular Events
MI : Myocardial Infarction
NSTEMI : Non-St Elevation Myocardial Infarction
P2Y12 : Purinergic Receptor Type Y Subtype12
OCT : Optical Coherence Tomography
SD : Standard Deviation
STEMI : St Elevation Myocardial Infarction
TLR : Target Lesion Revascularization
TVR : Target Vessel Revascularization
USAP : Unstable Angina Pectoris,=

1. INTRODUCTION

In-stent restenosis (ISR) is the most common cause of stent failure (Madhavan et al. 2020). ISR is defined as a previous stent segment with >50% stenosis or up to 5 mm from stent edge (Mehran et al. 1999). Despite advancements in interventional techniques, such as scoring, cutting, and drug-coated balloons, as well as devices like excimer laser coronary angioplasty (ELCA), rotablation, and intra-vascular lithotripsy (IVL), ISR remains a persistent challenge. Drug eluting balloon (DEB)/ Drug coated balloon (DCB) is a new tool used in the management of ISR. Some studies suggest that DEB is non inferior to drug eluting stents (DES) in ISR (Gao et al. 2018). Imaging plays a vital role in understanding the mechanics of ISR. The current

study aims at understanding the mechanics, device synergy, treatment approach, role of imaging and long term results in patients with ISR.

2. METHODOLOGY

This study was a retrospective observational monocentric study conducted at Apollo Hospitals, Chennai on 50 patients with ISR from April 2022 to October 2023. One-year follow-up information was collected through outpatient records. Patients with a prior history of percutaneous coronary intervention (PCI) who presented with ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI), unstable angina, a positive stress test, or recurrent revascularization failure in either a bare-metal stent (BMS) or drug-eluting stent (DES) were included. Patients with ST-elevation myocardial infarction requiring coronary artery bypass graft, lesions treated with non-drug-coated balloons, left main restenosis, or evidence of thrombus were excluded. Early restenosis within 3 months of the index procedure was also excluded. The primary outcome variable was major adverse cardiac and cerebrovascular events (MACCE) which is a composite outcome that includes cardiovascular death, target lesion revascularization (TLR), target vessel revascularization (TVR), and myocardial infarction (MI). Statistical analysis was performed using SPSS (IBM, 28.0). Summary statistics were presented with Mean ± SD and frequency (percentage) for the continuous and categorical factors respectively. Chi square/Fisher's exact test was used to determine the association between two independent categorical factors. *P*-value <0.05 was considered statistically significant.

3. RESULTS

Table 1 represents the demographic characteristics of the patient population, and clinical presentation of patients with ISR. Table 2 demonstrates imaging and plaque modification devices used in the study. Analysis of ISR mechanisms revealed stent under-expansion in 48% of cases with stent boost. Neo-intimal hyperplasia was identified in 20% of patients and neoatherosclerosis was identified in 14% of individuals on imaging. As depicted in Table 3, the imaging group experienced a statistically significant decrease in MACCE. The majority of patients (78%) underwent implantation of a DES, while 22% received a DEB. No significant difference in outcomes was observed between patients treated with DEB and DES. (Table 4) Furthermore, the administration of ticagrelor or prasugrel to ISR patients was associated with a significant reduction in event rates. Poor drug compliance after index procedure was also a major contributor for ISR among the patients included in study.

Table 1. Demographic characteristic of the study population and clinical presentation

Parameters	(n=50), n (%)
Age in years	
Mean ± SD	62.7 ± 9.8
Gender	
Male	46 (92)
Female	4 (8)
Presentation	
STEMI	6 (12)
NSTEMI	8 (16)
USAP	28 (56)
CCS	8 (16)
Comorbidities	
DM	31 (62)
HTN	33 (66)
Dyslipidemia	22 (44)
COPD	9 (18)
CKD	6 (12)
Smoking habit	
Yes	9 (18)

SD: Standard deviation, STEMI: ST elevation myocardial infarction, NSTEMI: Non-ST elevation myocardial infarction, USAP: Unstable angina pectoris, CCS: Chronic coronary syndrome, DM: Diabetes mellitus, HTN: Hypertension, COPD: Chronic Obstructive Pulmonary Disease, CKD: Chronic Kidney Disease

Table 2. Clinical variables and Outcomes

Parameters	(n=50), n (%)
LVEF (%)	
Mean ± SD	51.6 ± 9.9
Angiographic Block (%)	
Mean ± SD	92.9 ± 5.3
Range	80 – 100
Imaging	26 (52)
Type of Imaging (In patients who underwent imaging)	
Optical Coherence Tomography	21 (42)
Intravascular ultrasound	5 (10)
Calcium management (Fig. 3)	
Excimer laser coronary angioplasty	23 (46)
Rotablation	1 (2)
OPN*	6 (12)
Cutting of Balloon	14 (28)
No. of Devices used	
0	17 (34)
1	23 (46)
2	9 (18)
3	1 (2)
Drug eluting stent	39 (78)
Drug Eluting Balloon	11 (22)
P2Y12 Inhibitor	
Clopidogrel	7 (14)
Prasugrel	8 (16)
Ticagrelor	35 (70)
1-year MACCE	11 (22)

**OPN – Non Compliant Balloon*

4. DISCUSSION

In-stent restenosis refers to the narrowing of a previously stented coronary artery lesion. The reported incidence of ISR is 5% to 10% (Bønaa et al. 2016). One-fourth of patients with ISR clinically present with acute myocardial infarction and the 30-day mortality varies between 10% and 25% (Dangas et al. 2010, Moussa et al. 2020, Palmerini et al. 2018, Nakatsuma et al. 2018). In our study, 14 patients (28%) with previous history of PCI presented with acute MI. Exaggerated hemostatic healing of the arterial wall after stent implantation can lead to neointimal hyperplasia (Dangas et al. 2010). In-stent neoatherosclerosis (Fig. 1) is characterised by the accumulation of foamy macrophages, necrotic core formation and calcification of intima at the site of stent implantation (in-stent or within 5 mm of stent edge) (Taniwaki et al. 2016). It is a chronic process. Our analysis revealed the incidence of neointimal hyperplasia as 20%, and that of neoatherosclerosis as 14%. The primary cause for ISR was stent under expansion which was evident by stent boost and Imaging (IVUS/OCT). The utilization of imaging during index PCI could have facilitated the identification and correction of stent under-expansion, potentially leading to a reduction in the incidence of ISR. The incidence of MACCE was lower in patients who underwent imaging-guided PCI. Imaging modalities such as intravascular ultrasound (IVUS) (Fig. 2) and optical coherence tomography (OCT) (Fig. 1) have significantly improved the precision and efficacy of PCI. It is therefore recommended that all patients with ISR subsequently undergo imaging-guided PCI. Ongoing randomized controlled trials are expected to further elucidate the role of OCT and IVUS imaging in optimizing therapy and improving outcomes in ISR (Ali et al. 2021, Shlofmitz et al. 2020).

Our study suggests that potent P2Y12 inhibitors like ticagrelor and prasugrel may be a better choice than clopidogrel for ISR patients along with good compliance from patient and pre discharge counselling, regular outpatient follow ups. This is supported by the higher MACCE rate observed in the clopidogrel group (4 out of 7 patients). Furthermore, results of the meta-analysis by Chen W et al. aligns with our

findings, demonstrating the superiority of ticagrelor and prasugrel over clopidogrel in preventing ST-segment elevation ISR (Chen et al. 2021).

Additionally, our study highlights the potential benefits of device synergy. Using two or more devices (Specialty balloons like OPN-NC balloons, cutting balloons and ELCA) for adequate plaque modification and lesion preparation in 10 patients resulted in a lower MACCE rate (only 2 events). These findings warrant further investigation.

Table 3. Association between clinical factors and MACCE at 1 year

Parameters	MACCE at 1 year		Overall, (n=50)	*P*-value*
	No, (n=39)	Yes, (n=11)		
Imaging				**0.016**
Yes	24 (61.5)	2 (18.2)	26 (52)	
No	15 (38.5)	9 (81.8)	24 (48)	
Type of imaging				**0.036**
None	15 (38.5)	9 (81.8)	24 (48)	
OCT	19 (48.7)	2 (18.2)	21 (42)	
IVUS	5 (12.8)	-	5 (10)	
DES**				0.688
Not used	8 (20.5)	3 (27.3)	11 (22)	
Used	31 (79.5)	8 (72.7)	39 (78)	
DEB***				0.688
Not used	31 (79.5)	8 (72.7)	39 (78)	
Used	8 (20.5)	3 (27.3)	11 (22)	
P2Y12 Inhibitor				**0.043**
Clopidogrel	3 (7.7)	4 (36.4)	7 (14)	
Prasugrel	6 (15.4)	2 (18.2)	8 (16)	
Ticagrelor	30 (76.9)	5 (45.5)	35 (70)	
Potent and less potent P2Y12 Inhibitor				
Clopidogrel	3 (7.7)	4 (36.4)	7 (14)	**0.034**
Prasugrel & Ticagrelor	36 (92.3)	7 (63.6)	43 (86)	
No. of devices used				0.959
0	13 (33.3)	4 (36.4)	17 (34)	
1	18 (46.2)	5 (45.5)	23 (46)	
2	7 (17.9)	2 (18.2)	9 (18)	
3	1 (2.6)	-	1 (2)	

**- Chi square/Fisher's exact test*

*** DES – Third Generation FDA Approved Des Were Used*

**** DEB/DCB- Sirolimus or Paclitaxel Coated FDA Approved Balloons Were Used*

*OCT: Optical Coherence Tomography, IVUS: Intravascular * Ultrasound*

Table 4. Association between DES and DEB according to MACCE at 1 year

MACCE at 1 year	DES	DEB, n (%)		*P*-value
		Not used	Used	
No, (n=39)	Not used	-	8 (100)	<0.001
	Used	31 (100)	-	
Yes, (n=11)	Not used	-	3 (100)	0.006
	Used	8 (100)	-	
Overall, (n=50)	Not used	-	11 (100)	<0.001
	Used	39 (100)	-	

DES: Drug eluting stent, DEB: Drug eluting balloon

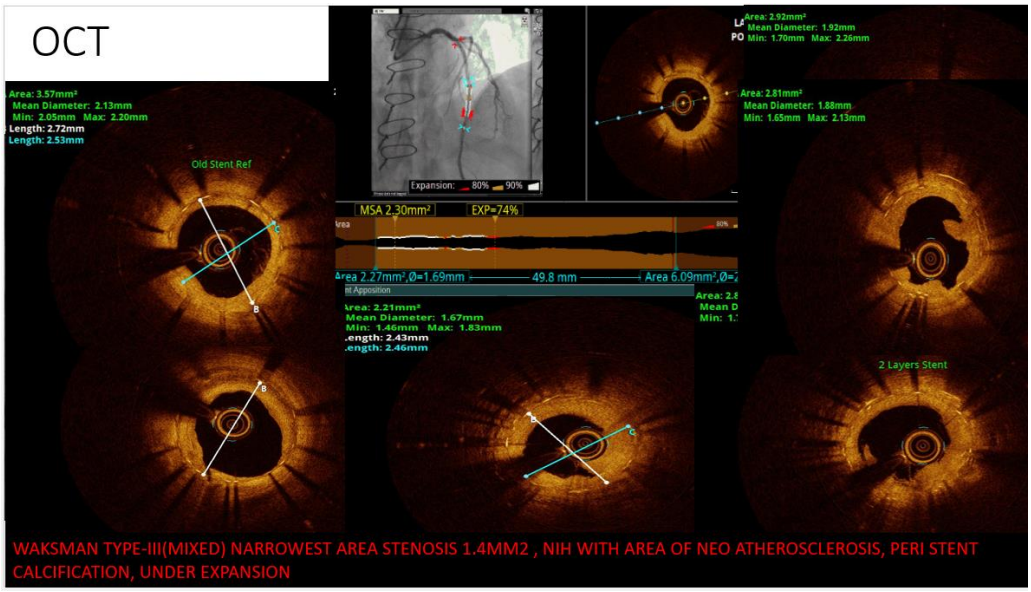

Fig. 1. OCT images demonstrating neoatherosclerosis, neointimal hyperplasia, persistent calcium & stent under expansion

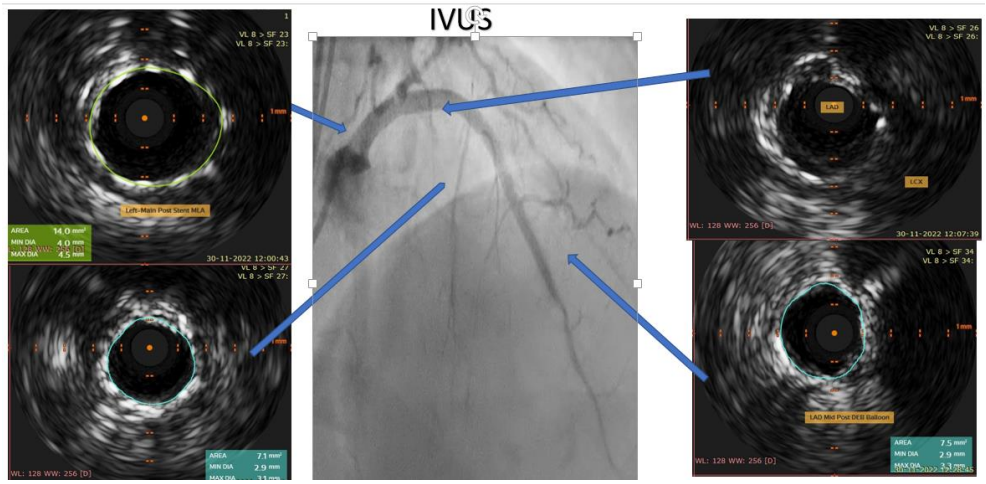

Fig. 2. Image showing Cine angiogram & Intra vascular ultra sound (IVUS) post stent deployment in a case of ISR for final optimal results

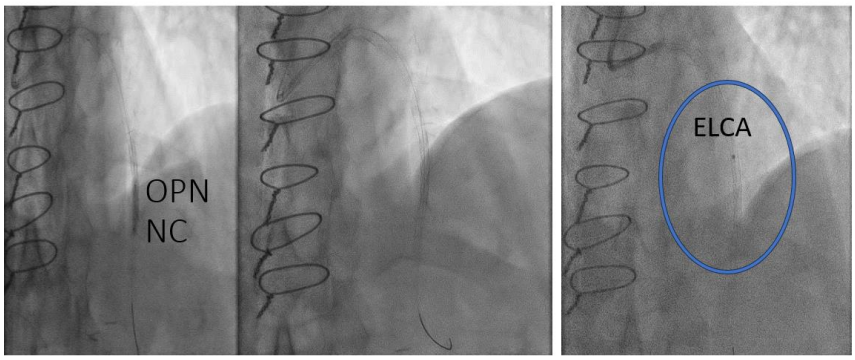

Fig. 3. Image shows use of speciality balloons OPN-NC & ELCA-excimer laser coronary angioplasty for adequate plaque modification, stent expansion & lesion preparation

This study was retrospective in nature and included a relatively small number of patients. Complete data regarding previous PCI procedures was not available for many participants. In cases where OCT/IVUS imaging was not performed, stent boosting was used to analyse the underlying mechanism of ISR. These factors could potentially limit the generalizability of our findings.

5. CONCLUSIONS

Our findings suggest that imaging-guided PCI can significantly reduce the incidence of major adverse cardiac events. Additionally, potent P2Y12 inhibitors like ticagrelor and prasugrel may offer superior outcomes to clopidogrel in ISR patients. While both adequate lesion preparation using ELCA or specialty balloons and understanding the mechanism of ISR using imaging (IVUS/OCT/Both) followed by drug-eluting balloons (DEBs) or drug-eluting stents (DES) or combining both demonstrated fairly similar outcomes in our study with a slight inclination towards imaging and ELCA for better long term results, further research and large number of studies is needed to assess their relative efficacy in ISR definitively.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

CONSENT

It is not applicable.

ETHICAL APPROVAL

Ethical clearance was obtained from the Institutional Review Board for the conduct of the study. [AMH-C-S-080/08-24]

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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