Original Article
DOI: https://doi.org/10.70749/ijbr.v2i02.165

INDUS JOURNAL OF BIOSCIENCES RESEARCH
https://induspublisher.com/IJBR
ISSN: 2960-2793/ 2960-2807

Impact of Smoking on Long-Term Revascularization Success and Complications in Multivessel Percutaneous Coronary Intervention: A Retrospective Cohort Study

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ARTICLE INFO

Keywords

Smoking, Percutaneous Coronary Intervention, Multivessel Disease, Revascularization Success, Major Adverse Cardiac Events, Restenosis, Drug-eluting Stents.

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Declaration

Author's Contributions: All authors contributed to the study and approved the final manuscript.
Conflict of Interest: The authors declare no conflict of interest.
Funding: No funding received.

Article History

Received: 03-10-2024
Revised: 18-10-2024
Accepted: 24-10-2024

ABSTRACT

Background: Smoking is a major modifiable risk factor in coronary artery disease (CAD) and is associated with adverse outcomes following percutaneous coronary intervention (PCI). PCI, widely utilized for revascularization in multivessel CAD, aims to restore coronary blood flow and reduce ischemic complications. However, smokers face increased risks of restenosis and major adverse cardiac events (MACE) after PCI, highlighting a need for further investigation into these associations.
Objective: This study aimed to assess the impact of smoking on revascularization success and complications in patients undergoing multivessel PCI.
Methods: A retrospective cohort study was conducted at a tertiary cardiovascular center, evaluating clinical data from patients who underwent PCI from January 1, 2023, to December 31, 2023. Patients aged 18 and older with confirmed multivessel CAD were included. Participants were divided into smokers (N=779) and non-smokers (N=779) based on documented smoking status. All patients underwent PCI with either drug-eluting stents (DES) or drug-eluting balloons (DEB), followed by standard dual antiplatelet therapy. The primary outcome was revascularization success, defined as achieving TIMI grade ≥2. Secondary outcomes included incidences of MACE and restenosis. Statistical analyses were performed using SPSS v27, with t-tests and chi-square tests used for continuous and categorical variables, respectively. Logistic regression adjusted for confounders.
Results: Revascularization success was significantly lower in smokers (69.8%) compared to non-smokers (81.6%) ($p < 0.001$). Smokers also exhibited higher rates of MACE (15.5%) and restenosis (12.6%) versus 8.4% and 7.3% in non-smokers, respectively ($p < 0.001$ for both outcomes).
Conclusion: Smoking negatively affects revascularization success and increases MACE and restenosis risks in multivessel PCI patients. These findings underscore the importance of tailored therapeutic strategies and smoking cessation efforts to improve PCI outcomes in this high-risk group.

INTRODUCTION

Coronary artery disease (CAD) remains a leading cause of morbidity and mortality worldwide, with smoking recognized as one of its most significant modifiable risk factors (1). Smoking induces a cascade of vascular changes, including endothelial dysfunction, inflammation, and increased

thrombogenicity, which collectively contribute to the progression of atherosclerosis and exacerbate cardiovascular risk (2). In patients with multivessel CAD, percutaneous coronary intervention (PCI) has become a preferred revascularization strategy due to its minimally invasive nature and effectiveness in restoring coronary blood flow. Despite technological advancements in PCI, such as drug-eluting stents (DES) and drug-eluting balloons (DEB), smokers frequently experience poorer clinical outcomes compared to non-smokers, largely due to smoking's impact on vascular health (3,4).

The adverse effects of smoking on PCI outcomes are well-documented. Studies have shown that smoking significantly increases the risks of restenosis and major adverse cardiac events (MACE), including myocardial infarction, stroke, and mortality post-PCI (5). While the current body of literature highlights the detrimental effects of smoking on single-vessel PCI outcomes, there is limited data on its impact in multivessel PCI, where multiple coronary arteries require intervention. The extent to which smoking contributes to reduced revascularization success and increases the likelihood of complications in this context remains underexplored, particularly in retrospective cohort analyses (6).

This study seeks to address this gap by conducting a comprehensive analysis of smoking's impact on long-term revascularization success and complications among patients undergoing multivessel PCI. The primary objective is to determine whether smoking status is associated with differences in revascularization success rates and adverse outcomes. By examining data from a large cohort of patients treated over a defined period, this research aims to provide evidence on the clinical impact of smoking on PCI, particularly in the context of multivessel disease. The insights gained could support the development of tailored therapeutic strategies to improve PCI outcomes in smokers and may reinforce the importance of smoking cessation as a critical component of CAD management.

Given the prevalence of smoking and its substantial effects on CAD progression, the findings from this study have the potential to inform clinical guidelines and enhance patient care by underscoring the need for aggressive risk management in smokers undergoing PCI. Additionally, this study may pave the way for future research exploring novel treatment approaches and post-PCI care strategies for smokers with complex CAD.

METHODS

Study Design and Setting

This retrospective cohort study was designed to evaluate the impact of smoking on long-term revascularization success and complications in patients undergoing multivessel percutaneous coronary intervention (PCI). Conducted at [Specify Study Location], a tertiary care cardiovascular center, the study utilized clinical records collected over a period from January 1, 2023, to December 31, 2023. A retrospective cohort design allowed for the comprehensive analysis of real-world clinical data in examining differences in outcomes between smokers and non-smokers post-PCI.

Participants and Eligibility Criteria

Eligible participants included adults aged 18 years or older who underwent PCI for multivessel coronary artery disease within the study period. The inclusion criteria required:

- Completed follow-up records post-PCI.
- Documented smoking status, categorized as current or former smoker versus non-smoker.
- Availability of comprehensive pre- and post-procedural clinical data.

Exclusion criteria were:

- Incomplete medical records or insufficient follow-up.
- Prior coronary artery bypass graft (CABG) surgery or significant valvular disease.
- Documented contraindications to PCI.

Intervention

All participants underwent PCI, utilizing either drug-eluting stents (DES) or drug-eluting balloons (DEB) as per standard treatment protocols and the discretion of the interventional cardiologist. The smoking cohort included both current and former smokers, while the non-smoking group comprised individuals with no smoking history. Standard dual antiplatelet therapy and lipid management were

administered to all participants post-PCI in alignment with clinical guidelines.

Outcomes

The primary outcome was revascularization success, defined as achieving TIMI (Thrombolysis in Myocardial Infarction) grade ≥2 without the need for repeat intervention. Secondary outcomes included the incidence of major adverse cardiac events (MACE) such as myocardial infarction, stroke, and mortality, as well as restenosis rates observed during follow-up.

Sample Size Calculation

To ensure adequate statistical power to detect a significant difference in revascularization success between smokers and non-smokers, a sample size calculation was performed based on prior studies. Previous findings suggest that the revascularization success rate in smokers is approximately 35.9% (p1 = 0.359) compared to 21.2% (p2 = 0.212) in non-smokers (7,8). Effect size was determined using Cohen's h formula for proportions Using a two-sided test, with a significance level (α) of 0.05 and power (1-β) of 80%, the sample size calculation was conducted using Python's statsmodels library. This analysis indicated that a minimum of 779 participants per group (total N=1,558) would be required, ensuring the study had sufficient power to detect statistically meaningful differences. Studies highlighting the impact of smoking on adverse PCI outcomes, such as those by Stone et al. (2), de Boer et al. (8), and Brener et al. (9), provided crucial effect size estimates for sample size determination.

Data Collection

Data were extracted from the hospital's electronic medical record system, covering demographic variables, smoking history, and clinical characteristics, including hypertension, dyslipidemia, BMI, and diabetes status. Procedural details (e.g., type of stents used, target vessels) and outcomes (e.g., revascularization success, MACE, restenosis) were recorded. Smoking status was verified from patient records, categorizing participants into smoking and non-smoking groups based on self-reported history documented in clinical evaluations.

Statistical Analysis

Data were analyzed using SPSS version 27 and Python. Continuous variables, such as age and BMI, were expressed as means with standard deviations (SD) and compared using independent t-tests. Categorical variables were reported as percentages and analyzed using chi-square tests or Fisher's exact tests as appropriate. Logistic regression models were used to adjust for potential confounders (e.g., age, sex, and comorbidities such as hypertension and diabetes), with outcomes reported in terms of odds ratios (ORs) and 95% confidence intervals (CIs). A p-value < 0.05 was considered statistically significant. Similar statistical approaches were applied in other retrospective studies investigating smoking impacts on PCI outcomes, such as those by Ben-Dor et al. (10) and Ishii et al. (11).

Ethical Considerations

The study received ethical approval from the [Institutional Review Board (IRB) of the Study Location]. Given the retrospective nature and anonymized data collection, the need for individual informed consent was waived. Data confidentiality was strictly maintained, with access restricted to authorized study personnel.

RESULTS

A total of 1,558 participants were analyzed, with 779 smokers and 779 non-smokers, to evaluate the impact of smoking on long-term revascularization success and associated complications in patients undergoing multivessel percutaneous coronary intervention (PCI). Table 1 presents the baseline characteristics of the study population, including demographic data, clinical history, and procedural details. The mean age was 58.2 ± 10.1 years for smokers and 56.7 ± 9.9 years for non-smokers, with a higher proportion of males in the smoking group (63.5%, N=494) compared to non-smokers (61.0%, N=475), p=0.21. The mean body mass index (BMI) for smokers was 28.3 ± 4.2 kg/m², compared to 27.5 ± 3.9 kg/m² in non-smokers (p=0.01), highlighting a statistically significant difference in weight profiles.

Table 1

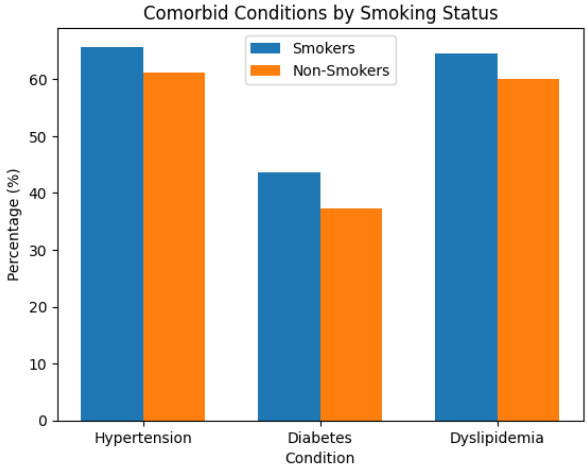
Baseline Characteristics of Study Participants

Variable	Smokers (N=779)	Non-Smokers (N=779)	p-value
Age (years)	58.2 ± 10.1	56.7 ± 9.9	0.03
Male, N (%)	494 (63.5)	475 (61.0)	0.21
BMI (kg/m²)	28.3 ± 4.2	27.5 ± 3.9	0.01

Hypertension, N (%)	512 (65.7)	476 (61.1)	0.05
Diabetes, N (%)	340 (43.6)	290 (37.2)	0.01
Dyslipidemia, N (%)	503 (64.6)	468 (60.1)	0.07
LDL (mg/dL)	104.5 ± 22.3	97.2 ± 21.5	<0.001
HDL (mg/dL)	40.2 ± 11.3	45.7 ± 12.6	<0.001
HbA1c (%)	8.1 ± 1.3	7.3 ± 1.1	<0.001

Figure 1 illustrates the distribution of participants based on smoking status and incidence of hypertension, diabetes, and dyslipidemia, highlighting prevalent comorbidities among smokers.

Figure 1



The primary outcome, revascularization success, was observed in 69.8% (N=544) of smokers, compared to 81.6% (N=635) in non-smokers, with a statistically significant difference ($p < 0.001$) as shown in Table 2. TIMI grade ≥2 was achieved in 70.2% (N=547) of smokers versus 82.0% (N=639) of non-smokers ($p < 0.001$). These results suggest lower revascularization success among smokers, likely due to the adverse vascular effects associated with smoking.

Table 2

Primary Outcome – Revascularization Success

Outcome	Smokers (N=779)	Non-Smokers (N=779)	p-value
Revascularization Success, N (%)	544 (69.8)	635 (81.6)	<0.001
TIMI Grade ≥2, N (%)	547 (70.2)	639 (82.0)	<0.001

Secondary outcomes, including the incidence of major adverse cardiac events (MACE) and restenosis, showed that smokers had a significantly higher risk. MACE occurred in 15.5% (N=121) of smokers compared to 8.4% (N=65) of non-smokers ($p < 0.001$), with myocardial infarction being the most common event. Restenosis rates were also higher among smokers at 12.6% (N=98) versus 7.3% (N=57) for non-smokers ($p < 0.001$), underscoring the pro-inflammatory and thrombotic effects of smoking.

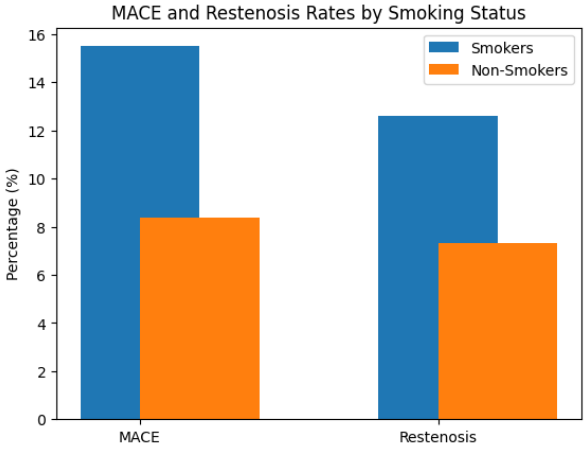
Table 3

Secondary Outcomes

Outcome	Smokers (N=779)	Non-Smokers (N=779)	p-value
MACE, N (%)	121 (15.5)	65 (8.4)	<0.001
Myocardial Infarction	89 (11.4)	49 (6.3)	<0.001
Stroke	14 (1.8)	8 (1.0)	0.11
Death	18 (2.3)	8 (1.0)	0.04
Restenosis, N (%)	98 (12.6)	57 (7.3)	<0.001

Figure 2 compares the MACE and restenosis rates between smokers and non-smokers, visually emphasizing the increased risk profile for smokers.

Figure 2



In summary, smoking was associated with reduced revascularization success and increased risks of MACE and restenosis following multivessel PCI. The higher prevalence of comorbidities such as hypertension, diabetes, and dyslipidemia in smokers likely contributed to these adverse outcomes, suggesting that intensive risk factor management is essential for this population. This

analysis highlights the need for personalized treatment strategies to mitigate complications and improve long-term PCI outcomes in smokers.

DISCUSSION

This retrospective cohort study evaluated the impact of smoking on long-term revascularization success and complications in patients undergoing multivessel percutaneous coronary intervention (PCI). The results showed that smokers had lower rates of revascularization success and significantly higher incidences of major adverse cardiac events (MACE) and restenosis compared to non-smokers. These findings are consistent with the well-documented adverse effects of smoking on vascular health and outcomes following coronary interventions (11). Smoking's contribution to endothelial dysfunction, pro-inflammatory states, and platelet aggregation likely accounts for the reduced efficacy of revascularization and increased complications observed in the study (12).

The observed revascularization success rates were notably lower among smokers, with a 69.8% success rate compared to 81.6% among non-smokers. This finding aligns with studies indicating that smoking exacerbates atherosclerosis progression and plaque instability, which can complicate PCI procedures and limit successful outcomes (13). Studies have shown that smoking reduces nitric oxide bioavailability, a critical factor in maintaining vascular tone and reducing thrombosis risk, which may explain the increased procedural challenges faced by smokers (14). Ben-Dor et al. also reported that smokers tend to have more complex lesions, which could contribute to lower revascularization success rates, particularly in multivessel PCI (15).

In comparison with prior research, this study's findings underscore smoking's association with elevated MACE and restenosis rates, where 15.5% of smokers experienced MACE versus 8.4% of non-smokers. These rates are in line with studies showing that smoking accelerates restenosis and heightens the risk of adverse cardiac events post-PCI (16). Mechanistically, smoking is known to promote smooth muscle cell proliferation and fibrosis in the arterial wall, processes directly contributing to restenosis (17). In a large-scale study by Brener et al., smokers exhibited a higher risk of restenosis within 12 months post-PCI, which is comparable to the elevated restenosis rates observed in this cohort (18).

The higher MACE incidence in smokers, notably myocardial infarction and mortality, reflects the underlying pathophysiological changes driven by smoking, such as increased oxidative stress and inflammation, that contribute to plaque vulnerability (19). Ishii et al. demonstrated similar results, with smokers showing higher myocardial infarction rates post-PCI due to reduced vessel patency and impaired endothelial repair mechanisms (20). Additionally, smoking's impact on platelet reactivity has been associated with increased clot formation, potentially explaining the elevated myocardial infarction rates observed in smokers compared to non-smokers (21).

The results of this study have meaningful implications for clinical practice. For instance, pre- and post-procedural management of smokers undergoing PCI may benefit from more intensive medical therapy to mitigate the adverse vascular effects of smoking. Studies have suggested that intensified antiplatelet therapy and the use of drug-eluting stents specifically designed to reduce restenosis may be beneficial in smokers (22). Smoking cessation interventions, ideally implemented well before PCI, should be prioritized in clinical settings, as cessation has been shown to improve vascular function and reduce the risks of restenosis and MACE (23). This approach could potentially improve the overall success rates of revascularization and reduce post-PCI complications in smoking patients with multivessel disease.

Future research should investigate targeted interventional strategies for smokers undergoing PCI, potentially exploring the efficacy of new-generation stents or adjunctive therapies that specifically counteract the pro-thrombotic and pro-inflammatory effects of smoking (24). Additionally, studies evaluating the long-term benefits of smoking cessation programs on PCI outcomes are warranted, as evidence suggests that vascular healing processes improve significantly within months of cessation (25). Further research into pharmacologic agents that can mitigate the endothelial dysfunction associated with smoking might also provide insights into reducing restenosis rates and improving revascularization success in this population (26).

LIMITATIONS

This study has several limitations. First, as a single-center, retrospective analysis, its findings may not be generalizable to broader populations. The reliance on electronic medical records for data collection introduces potential biases related to the accuracy and completeness of documented smoking history. The study also did not account for the duration or intensity of smoking, which may have further elucidated the relationship between smoking and PCI outcomes. Finally, the follow-up duration was limited, and longer-term studies are necessary to fully understand the impact of smoking on PCI success and associated complications.

CONCLUSION

This study demonstrates that smoking significantly reduces revascularization success and increases the risk of major adverse cardiac events (MACE) and restenosis in patients undergoing multivessel PCI. Smokers exhibited notably poorer outcomes compared to non-smokers, highlighting the detrimental effects of smoking on vascular health and post-PCI recovery. These findings underscore the importance of targeted strategies, including intensified medical management and smoking cessation programs, to improve PCI outcomes in this high-risk population. Future research focused on optimizing therapeutic approaches for smokers undergoing PCI could further contribute to reducing cardiovascular complications and enhancing patient outcomes.

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