

# Drug-Coated Balloon Percutaneous Coronary Intervention in ST-Elevation Myocardial Infarction (STEMI): A Novel Therapeutic Approach

Shah Hamayun<sup>1\*</sup>, Sania Ikram<sup>2</sup>, Aroosa Imtiaz Khan<sup>3</sup>, Haider Ali<sup>4</sup>, Faisal Amjad<sup>5</sup>, Zoha Waheed Abbasi<sup>2</sup>, Javeria Kulsoom<sup>2</sup>, Kiran Akbar<sup>3</sup>

<sup>1</sup>Department of Cardiology, Pakistan Institute of Medical Sciences (PIMS), Islamabad, Punjab 04485, Pakistan

<sup>2</sup>Department of Biological Sciences, National University of Medical Sciences (NUMS), Rawalpindi, Punjab, Pakistan

<sup>3</sup>Department of Pharmacy, Riphah International University, Islamabad, Punjab, Pakistan

<sup>4</sup>Department of Pharmacy, Kohat University of Science and Technology Kohat, Khyber Pakhtunkhwa, Pakistan

<sup>5</sup>Department of Nursing, Kohat University of Science and Technology, Kohat 26000, Khyber Pakhtunkhwa, Pakistan

Email: drshahhamayun499@gmail.com

**Abstract** – ST-elevation myocardial infarction (STEMI) is a life-threatening cardiovascular condition requiring immediate revascularization. Percutaneous coronary intervention (PCI) with drug-eluting stents (DES) has been the standard treatment; however, the long-term risks of in-stent restenosis (ISR), late stent thrombosis, and dual antiplatelet therapy (DAPT) complications necessitate alternative approaches. Drug-coated balloon (DCB) technology has emerged as a promising therapeutic strategy, offering advantages such as reduced foreign body implantation, homogenous drug delivery, and faster vascular healing. DCBs deliver antiproliferative drugs directly to the vessel wall, minimizing neointimal hyperplasia and restenosis. This review explores the efficacy, safety, and clinical outcomes of DCB-PCI in STEMI management. Additionally, we compare DCBs with DES and discuss their potential role in high-risk patient groups, including those with small vessels and bifurcation lesions. Challenges such as late lumen loss and the need for optimized patient selection criteria are also examined. Finally, ongoing clinical trials and future perspectives on integrating DCBs into mainstream STEMI treatment protocols are highlighted.

**Keywords** – ST-elevation myocardial infarction (STEMI), Percutaneous coronary intervention (PCI), Dual antiplatelet therapy (DAPT), Drug-eluting stent (DES), In-stent restenosis (ISR), Neointimal hyperplasia

## 1. Introduction

ST-elevation myocardial infarction (STEMI) remains a leading cause of morbidity and mortality worldwide [1, 2]. It results from the acute occlusion of a coronary artery due to plaque rupture and thrombus formation, necessitating urgent intervention to restore myocardial perfusion [3-6]. Traditional treatment strategies include thrombolysis and percutaneous coronary intervention (PCI), with PCI being the preferred approach due to its superior efficacy in reducing infarct size and improving survival rates [7, 8]. Over the years, drug-eluting stents (DES) have revolutionized STEMI management by mitigating restenosis through localized drug delivery, but concerns remain regarding in-stent restenosis (ISR), stent thrombosis, and prolonged dual antiplatelet therapy (DAPT) requirements [9-12].

Drug-coated balloons (DCBs) have emerged as a potential alternative to DES, especially in cases where stent implantation may not be ideal [12]. Unlike DES, which leave a permanent metallic scaffold, DCBs deliver antiproliferative drugs directly to the vessel wall without permanent implants [13, 14], promoting faster endothelial healing and reducing the risk of late thrombosis [15-17]. This innovation is particularly beneficial for patients with small vessel disease, bifurcation lesions, or those at high risk of bleeding complications associated with long-term DAPT [18-20].

Recent studies have demonstrated promising results for DCB use in STEMI, showing comparable efficacy to DES in

preventing restenosis while minimizing long-term complications [21, 22]. Clinical trials such as REVELATION [23] and PEPCAD NSTEMI [24] have suggested that DCBs can achieve favorable outcomes, particularly in carefully selected patient populations [25, 26]. However, challenges such as optimal patient selection, adequate lesion preparation, and concerns regarding late lumen loss need to be addressed before DCBs can be widely adopted in STEMI management [27-29].

This review provides a comprehensive analysis of DCB-based PCI in STEMI treatment, evaluating its clinical benefits, potential limitations, and future prospects. By integrating the latest evidence from clinical studies and trials, we aim to highlight the role of DCBs in contemporary interventional cardiology and their potential to redefine STEMI management protocols.

## 2. Mechanism of Action of Drug-Coated Balloons

DCBs function by delivering a controlled dose of antiproliferative drugs [30], such as paclitaxel or sirolimus, to the vessel wall via a hydrophilic excipient as illustrated in figure-1. Unlike DES, which continuously release drugs over time, DCBs provide rapid and localized drug uptake, reducing neointimal proliferation and restenosis [31, 32]. This mechanism eliminates the need for a permanent scaffold, allowing for more natural vessel healing and reducing the risk of chronic inflammation and late stent thrombosis [33-35].

Preclinical studies have demonstrated that DCBs achieve effective drug penetration within minutes of balloon inflation, with sustained biological effects lasting several weeks [36-38]. This approach is

particularly advantageous in lesions where stent implantation may lead to complications, such as small-diameter vessels, bifurcation sites, or ISR cases [39-41]

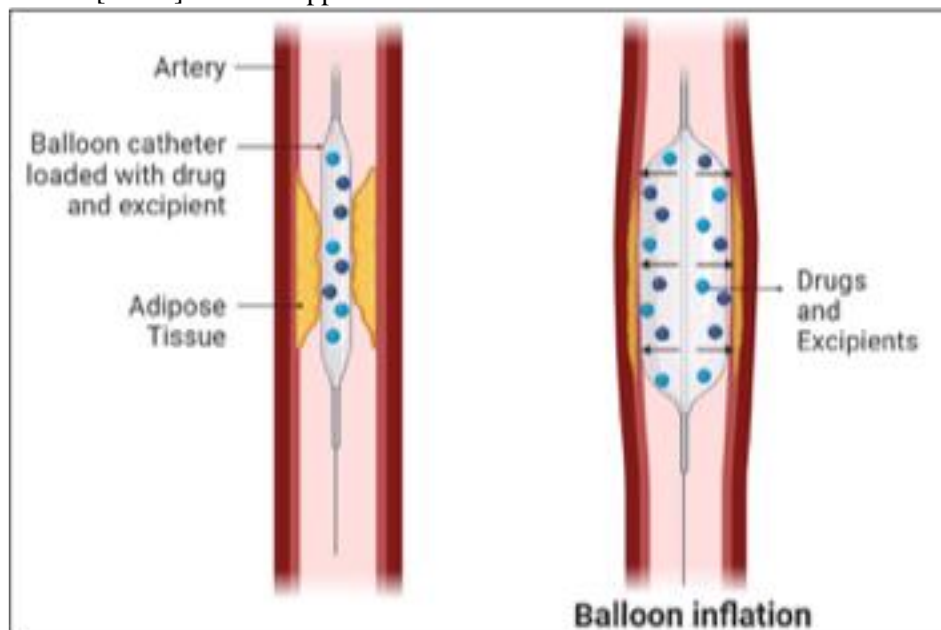


Figure 1. Mechanism of action of DCBs in coronary arteries, illustrating drug release and endothelial healing.

### 3. Clinical Evidence and Comparative Outcomes

Several randomized controlled trials have evaluated the efficacy and safety of DCBs in STEMI patients [42]. The REVELATION trial was a prospective, multicenter study comparing DCBs with DES in STEMI patients undergoing primary PCI [43]. It reported non-inferior outcomes in terms of late lumen loss, target lesion failure, and major adverse cardiac events (MACE) at 9-month follow-up. The trial suggested that DCBs provide a viable alternative to DES, particularly for patients with contraindications to stent placement [44, 45].

Similarly, the PEPCAD NSTEMI trial investigated the role of DCBs in non-ST-elevation myocardial infarction (NSTEMI) patients, demonstrating that DCBs could achieve restenosis rates comparable to DES while avoiding complications related to permanent stent implantation [12, 43, 46, 47]. The study highlighted that proper lesion preparation and adequate vessel sizing were crucial factors influencing clinical outcomes. Additionally, subgroup analyses from other trials have shown that DCBs may be particularly beneficial in cases involving small vessel disease, bifurcation lesions, and ISR treatment [48, 49].

A meta-analysis of multiple clinical trials further supported the efficacy of DCBs in STEMI treatment, indicating similar rates of target vessel revascularization (TVR) and myocardial infarction recurrence when compared to DES [50-52]. However, some concerns remain regarding late lumen loss, which underscores the need for optimized treatment protocols

and lesion preparation techniques to enhance drug

absorption and effectiveness [53, 54]

### 4. Advantages and challenges of DCBs in STEMI

One of the primary advantages of DCBs is the elimination of permanent metallic implants, leading to a lower risk of late stent thrombosis and a shorter duration of DAPT [49, 55]. Additionally, DCBs facilitate a more physiological vessel response, allowing for better remodeling and endothelial function as illustrated in figure-2. The absence of a metallic scaffold also makes future interventions more manageable, reducing complications in cases where repeat procedures are necessary [56, 57].

However, the success of DCB therapy is highly dependent on appropriate lesion preparation. Suboptimal balloon expansion, inadequate plaque modification, or residual dissections can impair drug delivery and increase the risk of restenosis [46, 58]. Additionally, DCBs may be less effective in heavily calcified lesions, where adequate drug penetration might be hindered. Late lumen loss, although generally minimal, remains a concern, necessitating further research into the long-term durability of DCB treatment [59]. rates of target vessel revascularization (TVR) and myocardial infarction recurrence when compared to DES [50-52]. However, some concerns remain regarding late lumen loss, which underscores the need for optimized treatment protocols and lesion preparation techniques to enhance drug absorption and effectiveness [53, 54].

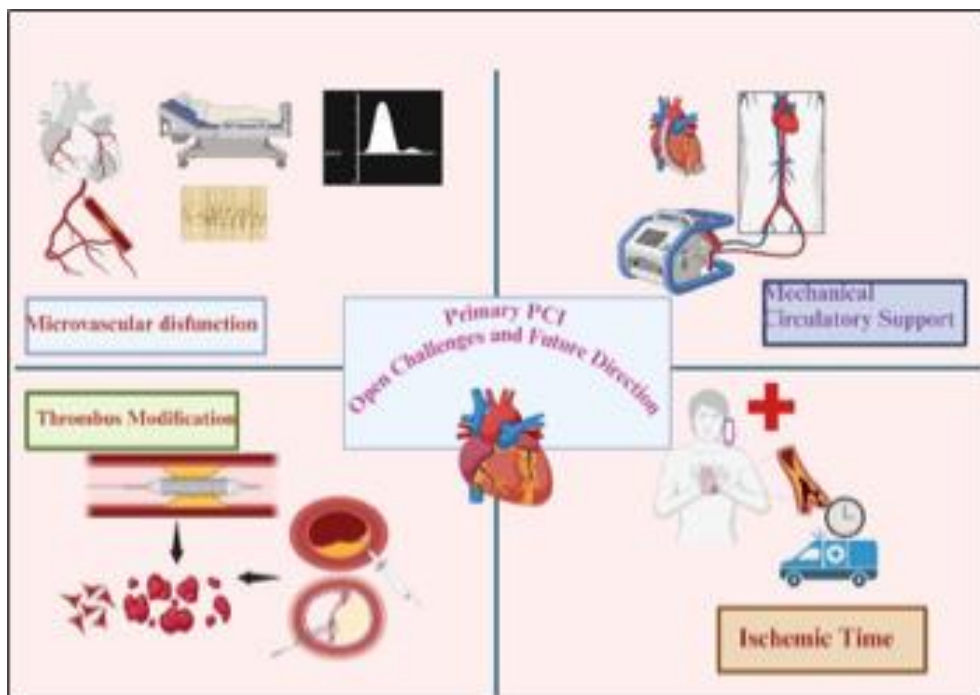


Figure 2. Mechanism of action of DCBs in coronary arteries, illustrating drug release and endothelial healing.

Table 1. Summary of Key Clinical Trials on DCB Use in STEMI

Trial Name	Study Design	Patient Population	Outcomes	Conclusion	References
REVELATION	RCT	STEMI patients	Non-inferior to DES in late lumen loss	DCBs are a viable alternative to DES in STEMI	[60, 61]
PEPCAD NSTEMI	RCT	NSTEMI patients	Comparable restenosis rates to DES	DCBs reduce adverse effects associated with stents	[43, 62]
ISAR-DESIRE 3	RCT	ISR patients	Lower restenosis rates than repeat DES	DCBs are superior for ISR management	[63]
BASKET-SMALL 2	RCT	Small vessel disease	Comparable efficacy to DES	DCBs avoid permanent stent complications	[64, 65]

### 5. Conclusion and future perspectives

Ongoing research aims to optimize DCB technology through novel drug formulations, improved balloon coatings, and enhanced delivery mechanisms. Advances in excipient technology are being explored to enhance drug retention and transfer efficiency, ensuring prolonged therapeutic effects. Additionally, research efforts are directed towards refining the pharmacokinetics of antiproliferative agents, such as sirolimus, to improve drug stability and bioavailability within the arterial wall. The development of next-generation DCBs with biodegradable coatings and hybrid drug delivery systems is also under investigation to address limitations associated with existing devices. These innovations hold the potential to maximize the clinical efficacy of DCBs while minimizing

risks such as late lumen loss and suboptimal drug absorption.

Future trials will focus on establishing standardized protocols for DCB use in STEMI patients and identifying subgroups that may derive the most benefit from this approach. One of the critical aspects under investigation is the optimization of lesion preparation techniques to enhance drug uptake and vessel healing. Studies are also exploring the use of imaging modalities such as intravascular ultrasound (IVUS) and optical coherence tomography (OCT) to guide DCB deployment, ensuring precise drug delivery. Furthermore, patient-specific factors, including comorbidities such as diabetes and chronic kidney disease, need to be carefully evaluated to determine the most appropriate treatment strategies. Large-scale randomized controlled trials will provide further clarity on the effectiveness of DCBs compared to drug-

eluting stents (DES) in various clinical scenarios. As interventional cardiology evolves, integrating DCBs into mainstream PCI strategies will validation through extensive clinical research. The current body of evidence suggests that DCBs hold significant promise in selected cases, particularly those where stent implantation poses challenges due to vessel size, anatomy, or previous intervention history. Patients at high risk for in-stent restenosis (ISR) or those requiring shorter durations of dual antiplatelet therapy (DAPT) may particularly benefit from DCBs. However, to ensure widespread adoption, training programs and guidelines must be developed to assist interventional cardiologists in mastering DCB techniques and understanding patient selection criteria.

Moreover, the cost-effectiveness of DCBs compared to traditional DES therapy needs thorough evaluation. Although DCBs reduce the risk of long-term complications associated with permanent metallic implants, the initial procedural costs and long-term economic impact remain areas of interest. Health economic studies are crucial to determining the financial viability of DCB implementation in routine clinical practice. Additionally, research into combination therapies, such as the use of DCBs alongside bioresorbable scaffolds or adjunctive pharmacological agents, may further enhance outcomes and expand the therapeutic applications of this technology.

With continued advancements in technology and procedural techniques, DCBs may play a crucial role in redefining STEMI management, offering a safer and more effective alternative to traditional stent-based interventions. The future of DCB therapy lies in personalized medicine approaches, leveraging precision diagnostics and patient-specific treatment algorithms to tailor interventions accordingly. As clinical experience grows and evidence accumulates, DCBs have the potential to revolutionize interventional cardiology by providing an innovative, non-permanent solution to coronary artery disease, ultimately improving patient outcomes and long-term cardiovascular health.

#### Acknowledgement:

Authors would like to acknowledge Department of cardiology, Pakistan Institute of Medical Sciences (PIMS), Islamabad, Pakistan.

#### Conflict of Interest

Authors have no conflict of interest to declare.

#### References

- [1] Vogel, B., et al., ST-segment elevation myocardial infarction. *Nature reviews Disease primers*, 2019. 5(1): p. 39.
- [2] Choudhury, T., N.E. West, and M. El-Omar, ST elevation myocardial infarction. *Clinical Medicine*, 2016. 16(3): p. 277-282.
- [3] Tibaut, M., D. Mekis, and D. Petrovic, Pathophysiology of myocardial infarction and acute management strategies. *Cardiovascular & Hematological Agents in Medicinal Chemistry (Formerly Current Medicinal Chemistry-Cardiovascular & Hematological Agents)*, 2016. 14(3): p. 150-159.
- [4] Ullah, M., et al., Stent as a Novel Technology for Coronary Artery Disease and Their Clinical Manifestation. *Curr Probl Cardiol*, 2023. 48(1): p. 101415.
- [5] Abbas, A., et al., A Comprehensive Review: Epidemiological Strategies, Catheterization and Biomarkers used as a Bioweapon in Diagnosis and Management of Cardio Vascular Diseases. *Curr Probl Cardiol*, 2023. 48(7): p. 101661.
- [6] Hasan, N., et al., Recent advancements of nitric oxide-releasing hydrogels for wound dressing applications. *Journal of Pharmaceutical Investigation*, 2023. 53(6): p. 781-801.
- [7] Angiolillo, D.J., et al., Antiplatelet therapy after percutaneous coronary intervention. *EuroIntervention*, 2022. 17(17): p. e1371.
- [8] Ullah, M., et al., Clindamycin-loaded polyhydroxyalkanoate nanoparticles for the treatment of methicillin-resistant *Staphylococcus aureus*-infected wounds. *Pharmaceutics*, 2024. 16(10): p. 1315.
- [9] Zeng, Y., et al., Drug-eluting stents for coronary artery disease in the perspective of bibliometric analysis. *Frontiers in Cardiovascular Medicine*, 2024. 11: p. 1288659.
- [10] Kožlik, M., et al., Drug-eluting stents: Technical and clinical progress. *Biomimetics*, 2023. 8(1): p. 72.
- [11] Mukheja, Y., et al., Unravelling the progress and potential of drug-eluting stents and drug-coated balloons in cardiological insurgencies. *Life Sciences*, 2024: p. 122908.
- [12] Ullah, M., et al., Shaping the Future of Cardiovascular Disease by 3D Printing Applications in Stent Technology and its Clinical Outcomes. *Curr Probl Cardiol*, 2024. 49(1 Pt A): p. 102039.
- [13] Korjian, S., et al., Drug-coated balloons in the management of coronary artery disease. *Circulation: Cardiovascular Interventions*, 2024. 17(5): p. e013302.
- [14] Maina, B.W., et al., Effectiveness of school-based interventions in delaying sexual debut among adolescents in sub-Saharan Africa: a protocol for a systematic review and meta-analysis. *BMJ open*, 2021. 11(5): p. e044398.
- [15] Marlevi, D. and E.R. Edelman, Vascular lesion-specific drug delivery systems: JACC state-of-the-art review. *Journal of the American College of Cardiology*, 2021. 77(19): p. 2413-2431.
- [16] Qamar, S.U.R., et al., Treatment of peripheral artery disease using injectable biomaterials and drug-coated balloons: safety and efficacy perspective. *Pharmaceutics*, 2023. 15(7): p. 1813.
- [17] Ullah, M., et al., Shaping the future of cardiovascular disease by 3D printing applications in stent technology and its clinical outcomes. *Current Problems in Cardiology*, 2024. 49(1): p. 102039.
- [18] Zimarino, M., et al., Antithrombotic therapy after percutaneous coronary intervention of bifurcation lesions: Antithrombotic drugs in bifurcation PCI. *EuroIntervention*, 2021. 17(1): p. 59.
- [19] Mihatov, N., et al., Individualizing Dual Antiplatelet Therapy (DAPT) Duration Based on Bleeding Risk, Ischemic Risk, or Both: An Analysis From the DAPT Study. *Cardiovascular Revascularization Medicine*, 2022. 41: p. 105-112.
- [20] Abbas, A., et al., A comprehensive review: epidemiological strategies, catheterization and biomarkers used as a bioweapon in diagnosis and management of cardio vascular diseases. *Current Problems in Cardiology*, 2023. 48(7): p. 101661.
- [21] Megaly, M., et al., Systematic review and meta-analysis of short-term outcomes with drug-coated balloons vs. stenting in acute myocardial infarction. *Cardiovascular Intervention and Therapeutics*, 2021. 36: p. 481-489.
- [22] Ullah, M., et al., Coronavirus and its terrifying inning around the globe: The pharmaceutical cares at the main frontline. *Chemosphere*, 2021. 275: p. 129968.
- [23] Schwartz, A.L., et al., Why diverse clinical trial participation matters. *New England Journal of Medicine*, 2023. 388(14): p. 1252-1254.
- [24] Fezzi, S., et al., Drug-Coated Balloon in Acute Coronary Syndromes: Ready for the Prime Time? *Current Cardiology Reports*, 2024. 26(5): p. 359-372.
- [25] Shaikh, S.I., et al., Outcomes of drug (paclitaxel) coated balloons in various coronary lesion subsets; A two-year follow-up study. *Pakistan Journal of Cardiovascular Intervention*, 2023. 3(2): p. 01-12.
- [26] Khan, S.U., et al., Nanotherapeutic approaches for transdermal drug delivery systems and their biomedical applications. *European Polymer Journal*, 2024. 207: p. 112819.
- [27] Jelovečki Đokić, Z., Results of Percutaneous Interventions with Drug Coated Balloons in Diabetic Patients with de novo Coronary Artery Lesions in University Hospital Center Zagreb. 2023, University of Zagreb. School of Medicine.
- [28] Jiang, J.-L., Q.-J. Huang, and M.-H. Chen, Efficacy and safety of drug-coated balloon for de novo lesions of large coronary arteries: Systematic review and meta-analysis of randomized controlled trials. *Heliyon*, 2024. 10(3).

- [29] Greco, A., et al., Expanding indications for drug-coated balloons in coronary artery disease. *Expert Review of Medical Devices*, 2025(just-accepted).
- [30] Wei, T.H., Development of Robust Amphiphilic Coating for Drug Coated Balloon. 2021, National University of Singapore (Singapore).
- [31] DePietro, D.M. and S.O. Trerotola, Choosing the right treatment for the right lesion, Part II: a narrative review of drug-coated balloon angioplasty and its evolving role in dialysis access maintenance. *Cardiovascular Diagnosis and Therapy*, 2023. 13(1): p. 233.
- [32] Liu, S., et al., A randomized comparison of 2 different drug-coated balloons for in-stent restenosis. *Cardiovascular Interventions*, 2023. 16(7): p. 759-767.
- [33] Shen, Y., et al., Development of biodegradable polymeric stents for the treatment of cardiovascular diseases. *Biomolecules*, 2022. 12(9): p. 1245.
- [34] Leeser, M.A. and M.D. Feldman, Thrombosis and myocardial infarction: the role of bioresorbable scaffolds. *The journal of cardiovascular aging*, 2023. 3(1): p. 7.
- [35] Wu, X., et al., Current perspectives on bioresorbable scaffolds in coronary intervention and other fields. *Expert Review of Medical Devices*, 2021. 18(4): p. 351-366.
- [36] Fensterseifer Schmidt, A., Multiphysics simulation of drug-coated balloon deployment and drug delivery. 2024, University of Glasgow.
- [37] Sato, Y., et al., Local, downstream, and systemic evaluation after femoral artery angioplasty with Kanshas drug-coated balloons in vitro and in a healthy swine model. *Journal of Vascular and Interventional Radiology*, 2023. 34(7): p. 1166-1175. e2.
- [38] Dangler, A., Research Model Applications in the Investigation of Vascular Disease Treatments. 2023, University of South Dakota.
- [39] Raj, B., et al., Small Diameter Stents In Cardiovascular Applications. *Chemistry & Biodiversity*: p. e202402008.
- [40] Olorunfemi, O. and C.E. Alfonso, Revascularization of complex coronary lesions: the importance of vessel and plaque preparation strategies, in *Debulking in Cardiovascular Interventions and Revascularization Strategies*. 2022, Elsevier. p. 181-220.
- [41] Song, X., et al., Clinical Outcomes of Self-Made Polyurethane-Covered Stent Implantation for the Treatment of Coronary Artery Rforations. *Journal of Interventional Cardiology*, 2021. 2021(1): p. 6661763.
- [42] Hao, X., et al., Study on the safety and effectiveness of drug-coated balloons in patients with acute myocardial infarction. *Journal of Cardiothoracic Surgery*, 2021. 16: p. 1-7.
- [43] Abdelaziz, A., et al., Drug-coated balloons versus drug-eluting stents in patients with acute myocardial infarction undergoing percutaneous coronary intervention: an updated meta-analysis with trial sequential analysis. *BMC Cardiovascular Disorders*, 2023. 23(1): p. 605.
- [44] Yu, X., et al., A non-inferiority, randomized clinical trial comparing paclitaxel-coated balloon versus new-generation drug-eluting stents on angiographic outcomes for coronary de novo lesions. *Cardiovascular Drugs and Therapy*, 2022: p. 1-10.
- [45] Ullah, A., M. Ullah, and S.I. Lim, Recent advancements in nanotechnology based drug delivery for the management of cardiovascular disease. *Current problems in cardiology*, 2024. 49(4): p. 102396.
- [46] Khan, M.A., et al., 3D printing technology and its revolutionary role in stent implementation in cardiovascular disease. *Current Problems in Cardiology*, 2024: p. 102568.
- [47] Alifah, N., et al., Development of clindamycin-releasing polyvinyl alcohol hydrogel with self-healing property for the effective treatment of biofilm-infected wounds. *Gels*, 2024. 10(7): p. 482.
- [48] Jeger, R.V., et al., Drug-coated balloons for coronary artery disease: third report of the international DCB consensus group. *Cardiovascular Interventions*, 2020. 13(12): p. 1391-1402.
- [49] Mutema, M., et al., Systematic Review on Role of Drug Eluting Stent (DES) Versus Drug-Coated Balloon (DCB) in Small Vessel Coronary Artery Disease. *Current Cardiology Reports*, 2024. 26(7): p. 681-688.
- [50] Fang, Z., et al., Drug-coated balloon vs. drug-eluting stent in acute myocardial infarction: a systematic review and updated meta-analysis. *Anatolian Journal of Cardiology*, 2023. 27(8): p. 444.
- [51] Kokkinidis, D.G., et al., Second-generation drug-eluting stents versus drug-coated balloons for the treatment of coronary in-stent restenosis: A systematic review and meta-analysis. *Catheterization and Cardiovascular Interventions*, 2018. 92(2): p. 285-299.
- [52] Ullah, M., et al., Carbon Dots: New Rising Stars in the Carbon Family for Diagnosis and Biomedical Applications. *Journal of Nanotheranostics*, 2024. 6(1): p. 1.
- [53] Kumar, M., et al., Comparison of Drug-Coated Balloon to Drug Eluting Stent in Patients with In-Stent Restenosis: A Systematic Review and Meta-Analysis. *The American Journal of Cardiology*, 2024.
- [54] Waleed, A., et al., Nanotechnology and biomedical devices used as a novel tool in biosensing and bioimaging of disease. *Journal of Women Medical and Dental College*, 2023. 1(4).
- [55] Safdar, M., et al., Genomic insights into heart health: Exploring the genetic basis of cardiovascular disease. *Current Problems in Cardiology*, 2024. 49(1): p. 102182.
- [56] Laubach, M., et al., The concept of scaffold-guided bone regeneration for the treatment of long bone defects: current clinical application and future perspective. *Journal of functional biomaterials*, 2023. 14(7): p. 341.
- [57] Merinopoulos, I., et al., Percutaneous coronary intervention in the elderly: are drug-coated balloons the future? *Current cardiology reviews*, 2018. 14(1): p. 45-52.
- [58] Rathore, S., et al., Drug coated balloons and their role in bifurcation coronary angioplasty: appraisal of the current evidence and future directions. *Expert Review of Medical Devices*, 2020. 17(10): p. 1021-1033.
- [59] Caminiti, R., et al., Drug-coated balloon versus drug-eluting stent for treating de novo large vessel coronary artery disease: a systematic review and meta-analysis of 13 studies involving 2888 patients. *Clinical Research in Cardiology*, 2024: p. 1-13.
- [60] Cortese, B. and E. Sanchez-Jimenez, Back to the future: DCB use instead of DES for the treatment of complex, native coronary artery disease. *European Heart Journal Supplements*, 2021. 23(Supplement\_E): p. E63-E67.
- [61] Wang, Z., et al., New Ultrasound-Controlled Paclitaxel Releasing Balloon vs. Asymmetric Drug-Eluting Stent in Primary ST-Segment Elevation Myocardial Infarction—A Prospective Randomized Trial—. *Circulation Journal*, 2022. 86(4): p. 642-650.
- [62] Khan, S.U., et al., Single-cell RNA sequencing (scRNA-seq): advances and challenges for cardiovascular diseases (CVDs). *Current problems in cardiology*, 2024. 49(2): p. 102202.
- [63] Kufner, S., et al., Neointimal modification with scoring balloon and efficacy of drug-coated balloon therapy in patients with restenosis in drug-eluting coronary stents: a randomized controlled trial. *JACC: Cardiovascular Interventions*, 2017. 10(13): p. 1332-1340.
- [64] Mangner, N., et al., Safety and efficacy of drug-coated balloons versus drug-eluting stents in acute coronary syndromes: a prespecified analysis of BASKET-SMALL 2. *Circulation: Cardiovascular Interventions*, 2022. 15(2): p. e011325.
- [65] Gao, C., et al., Drug-coated balloon angioplasty with provisional stenting versus primary stenting for the treatment of de novo coronary artery lesions: REC-CAGEFREE I trial rationale and design. *BMC Cardiovascular Disorders*, 2024. 24(1): p. 319