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Coronary Artery Bypass Grafting (CABG) After Failed Percutaneous Coronary Intervention (PCI): Integrative Review

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Abstract
Background. The dynamic development of interventional cardiology and the widespread use of drug-eluting stents (DES) have made percutaneous coronary intervention (PCI) the first-line treatment for many forms of coronary artery disease. However, phenomena such as in-stent restenosis (ISR), late stent thrombosis and the natural progression of multivessel atherosclerosis contribute to a growing population of patients requiring a shift toward surgical treatment (prior-PCI patients). Coronary artery bypass grafting (CABG) remains the gold standard for managing advanced coronary artery disease, including cases of failed prior percutaneous interventions.
Aim. The aim of this study is to review the literature regarding the outcomes of CABG following failed PCI and to assess the impact of this surgical procedure on patient health and survival.
Material and methods. A literature review (2016–2026) was conducted using the PubMed database, focusing on CABG procedures performed after prior PCI. An integrative approach was used to evaluate clinical outcomes, baseline risk factors, complication rates and duration of hospitalization.
Results. Research findings suggest that patients undergoing CABG after prior PCI present with a significantly higher baseline operative risk, more complex coronary anatomy and a higher burden of comorbidities, particularly diabetes, compared to primary CABG patients. Although a history of multiple PCIs is associated with technically more demanding surgeries and a slightly increased risk of postoperative complications, CABG consistently provides superior long-term survival and lower rates of repeat revascularization.
Conclusions. The analysis highlights that despite the increased baseline clinical risk, CABG remains a highly effective, safe and definitive salvage strategy for patients with exhausted percutaneous options. Careful qualification by a multidisciplinary Heart Team is essential in this high-risk group.

Keywords: coronary artery bypass grafting, percutaneous coronary intervention, in-stent restenosis, surgical revascularization, prior-PCI

1. **Introduction**

Coronary artery disease (CAD) remains a major global health issue, contributing significantly to both morbidity and mortality worldwide. [1] It is currently the third leading cause of death globally, associated with 17.8 million of fatalities annually. [2] The risk factors for developing CAD include advanced age, male gender, hypertension, dyslipidemia, diabetes mellitus, obesity, smoking and a sedentary lifestyle. [3]

The first-line management for chronic coronary syndromes (CCS) involves optimal medical therapy; however, the presence of persistent clinical symptoms is an indication for revascularization. [4] In case of CCS and non-ST-segment elevation myocardial infarction (NSTEMI) the choice between percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) depends on multiple factors and this complex decision should be made by a multidisciplinary Heart Team. In the case of STEMI, PCI remains the gold standard. [5] Currently, PCI is the most commonly performed revascularization procedure worldwide. It is estimated that over 3 million stent implantations are performed annually. However, despite continuous advances in drug-eluting stent (DES) technology, PCI failure remains a growing clinical challenge. The primary mechanisms causing this failure are in-stent restenosis (ISR) and late stent thrombosis. These adverse events are often triggered by mechanical issues during the procedure, such as coronary stent underexpansion. [6] Another well-documented risk factor for restenosis is comorbidities such as diabetes. [7] Long-term follow-up studies regarding treatment of left main coronary artery disease (LMCAD), demonstrate that primary PCI is associated with higher risk of repeat revascularization compared with primary CABG. [8] When percutaneous treatment options are exhausted or when the natural progression of multivessel disease occurs, CABG becomes the definitive salvage strategy.

The aim of this integrative review is to evaluate the clinical profile, indications and early to long-term outcomes of treatment in patients undergoing CABG due to the exhaustion of percutaneous treatment options.

2. Research material and methods

A literature search was conducted using the PubMed database in 2026, to identify relevant studies published between 2016 and 2026. Research was focused on studies regarding CABG performed after prior, failed PCI. The search strategy relied on combinations of the following keywords and phrases: "coronary artery bypass grafting", "CABG", "percutaneous coronary intervention", "prior PCI", "previous PCI", "in-stent restenosis" and "stent thrombosis". Additionally, crucial earlier publications (including meta-analyses from 2015) identified through manual cross-referencing of the included articles were incorporated into the final analysis.

An integrative review method was used to synthesize the data regarding patient characteristics, early and long-term mortality, major adverse cardiovascular events (MACE) and the need for repeat revascularization. The inclusion criteria were limited to meta-analyses, systematic reviews, observational cohort studies and clinical trials published in English. Articles focusing on primary CABG without a prior-PCI comparison group, isolated case reports and studies examining non-coronary vascular interventions were excluded.

3. Research results

3.1. Early Postoperative Outcomes

The impact of prior percutaneous coronary intervention (PCI) on postoperative outcomes of coronary artery bypass grafting (CABG) remains a subject of clinical debate.

A meta-analysis of 36 recent studies by Zhang et al., including a total of 308,000 CABG patients, of whom 40,892 (13.3%) had received prior PCI, found that prior PCI was associated with a higher risk of early all-cause mortality (in-hospital or within 1 month) and major adverse cardiovascular events (MACE). However, no association was found between PCI and late mortality. It is noteworthy that when patients with acute PCI failure were excluded from the analysis, similar results were obtained for early all-cause mortality, early MACE and late all-cause mortality. The only available multivariate study that excluded patients with acute PCI failure showed that prior PCI was not associated with late MACE after CABG. It is worth emphasizing that meta-regression analyses did not reveal a significant effect of study characteristics, including patient number, age, gender, diabetes status, percentage of patients with prior PCI and follow-up duration, on the results.[9]

The authors of the discussed meta-analysis attributed the increased risk of early death in patients undergoing CABG after PCI to an increased inflammatory response and endothelial dysfunction of the angioplasty vessel, which may lead to an increased risk of vascular events after CABG in patients with prior PCI. Second, because anastomosis during CABG can be performed in segments of coronary arteries already stent-loaded, prior PCI with stents may technically complicate the CABG procedure, limiting the possibility of performing a distal anastomosis. Furthermore, prior PCI may impair blood flow in collateral vessels, which may therefore affect graft patency after CABG. Finally, prior PCI before CABG may be a marker of overall poor clinical condition and a high burden of atherosclerotic lesions, which may also lead to a poor prognosis in the acute phase after CABG. [9]

The results of the prospective E-CABG (European Multicenter Coronary Artery Bypass Grafting) registry conducted at 16 European centers by Mariscalco et al. on 3,641 adult patients, 685 (19%) of whom had a history of PCI, provide a different perspective. In this cohort, patients with prior PCI exhibited different characteristics compared to those undergoing primary CABG. Patients with prior PCI were younger (66.4 ± 9.4 vs. 67.6 ± 9.3 years; p = 0.0025) and had lower Syntax scores (26.5 ± 10.4 vs. 28.6 ± 10.9; p = 0.0001). However after adjusting the control group using propensity scores, no clinical deifferences between the groups were observed. [10]

In both the unweighted and weighted patient groups, prior PCI was not associated with increased in-hospital mortality (odds ratio 0.73; 95% confidence interval 0.29–1.38; P=0.33 and odds ratio 0.90; 95% confidence interval 0.39–2.08; P=0.81, respectively). Sensitivity analyses and variable interactions confirmed that in-hospital mortality rates were similar in both patient groups regardless of sex, age classes, Syntax score categories, left ventricular ejection fraction classes, eGFR classes (≤60 mL/min per 1.73 m2) and presence of diabetes mellitus. [10]

Furthermore, prior PCI did not increase the risk of major postoperative complications. The occurrence of stroke, acute kidney injury, atrial fibrillation and gastrointestinal complications

was similar in both the weighted and unweighted groups. Aditionaly, post-PCI patients did not require more frequent reexploration for bleeding/tamponade, intensive care unit stay, blood transfusions, or mechanical circulatory support such as intra-aortic balloon pump or extracorporeal membrane oxygenation support. [10]

It is important to note, that analysis of the E-CABG registry excluded 120 patients who had undergone PCI <30 days prior to CABG . This specific high-risk subgroup presented different clinical characteristic. Patients with a recent PCI demonstrated a significantly higher mortality rate (3.3% vs. 1.6%) and morbidity. This included an increased requirement for prolonged inotropic support, higher rate of stroke (2.5% vs. 1.9%) and surgical reexploration due to postoperative bleeding (5.0% vs. 2.0%). Conversely, in the main study cohort where outcomes remained comparable to primary CABG, the average time between the last percutaneous intervention and surgery was significantly longer, amounting to 46 months. [10]

This discrepancy in the literature suggests that the overall statistical risk in case of prior PCI might be higher in large, unselected retrospective cohorts. However the individual early surgical risk is likely heavily modulated by specific baseline characteristics, the urgency of the procedure and modern institutional practices.

3.2. Late Postoperative Outcomes

Long-term prognosis in patients undergoing CABG after prior PCI is crucial for evaluating the efficacy of this salvage strategy. There is conflicting evidence regarding this topic.

A meta-analysis of 31 studies by Luthra et al., including a total of over 218,000 patients (of whom over 23,000 had undergone prior percutaneous interventions) across an 18-year period, provides insights into this issue. Data revealed that a history of percutaneous intervention had no negative impact on patientm survival (inverse rate ratio: 1.12, 95% confidence interval: 0.98-1.27, P = 0.110). Furthermore, the mortality risk connected to previous stenting has shown a significant downward trend over the past twenty years. This phenomenom is likely caused by continuous advancements in surgical techniques and improved perioperative care. [11]

Nevertheless, despite comparable survival rates, the prior-PCI cohort experiences a significantly higher rate of early and late major adverse cardiovascular events (MACE) compared to patients undergoing primary CABG (odds ratio 1.26; 95% CI 1.02–1.55; p = 0.03). Furthermore, the analysis revieled that studies, where the group of patients after PCI was larger, reported higher relative mortalities. Treatment effects varied significantly between studies. This observations suggest that higher institutional rates of patients after PCI, may be associated with higher mortality.[11]

Similarly, a meta-analysis conducted by Zhang et al., including 36 studies and over 308,000 patients, demonstrates that previous percutaneous interventions do not negatively impact long-term mortality (across observation periods from 1 to 13 years). [9]

However, contrary to some reports, this study provided evidence that the prior-PCI cohort did not experience a significantly higher risk of late MACE (OR: 1.03, 95% CI: 0.97–1.09, p = 0.38, I^2 = 0%). The analysis demonstrated that a history of stenting was exclusively correlated with elevated rates of early MACE. Furthermore, to eliminate potential bias, the authors performed a sensitivity analysis restricted only to multivariable studies that excluded patients with acute PCI failure. This sub-analysis confirmed the elevated risks of early mortality (OR:

1.25, p = 0.003) and early MACE (OR: 1.50, p = 0.001) and lack of association with late mortality (OR: 1.03, p = 0.70) in this specific patient cohort. [9]

3.3. Anatomical Complexity and Surgical Challenges

A crucial aspect of understanding the outcomes of CABG in prior-PCI patients lies in the local anatomical complexity of the stented coronary vessels. While the overall demographic profile and total atherosclerotic burden may vary—with some large registries even reporting younger ages and lower baseline SYNTAX scores in prior-PCI patients [10]—the local surgical environment is consistently more demanding.

Furthermore, percutaneous interventions carry procedural risk factors for in-stent restenosis (ISR). Mechanical issues such as stent malapposition, stent underexpansion, geographical lesion miss, stent deformation or fracture and distal edge dissections significantly contribute to vessel failure. The risk is further amplified by stent overlapping, multiple stent layers, or the use of bare-metal stents (BMS). [12] These mechanical factors, combined with the natural progression of atherosclerosis and the inflammatory, neointimal hyperplasia induced by previously implanted stents, often lead to diffuse coronary artery disease within the treated segments.

As studies show, the PCI procedure itself carries additional risks. The mechanical disruption of epicardial plaques during the initial percutaneous intervention causes the release of atherothrombotic debris and vasoactive molecules downstream into the coronary circulation. While solid fragments physically occlude the capillary bed, the release of soluble factors causes endothelial dysfunction and facilitates vasoconstriction. This phenomenon leads to patchy microinfarcts and an inflammatory reaction. Ultimately, these often clinically silent periprocedural injuries may cause progressive myocardial contractile dysfunction. [13]

The presence of multiple stents creates more challenging environment for CABG. Anastomoses must be performed in segments that are already heavily stent-loaded, wchich results in a more time-consumimg procedure requiring a higher number of grafts. Consequently CABG in this group of patients require longer aortic cross-clamp and cardiopul-monary bypass times. [14] The clinical consequences of this highly compromised surgical environment are significant. As demonstrated by Biancari et al., while a history of multiple prior percutaneous interventions does not necessarily increase short-term or long-term mortality, it significantly elevates the risk of late myocardial infarction and the need for repeat revascularization at 5 years post-CABG. [15]

To overcome these issues and restore lumen patency in vessels, surgeons are frequently forced to utilize demanding adjunctive maneuvers such as coronary endarterectomy (CE). However, recent real-world data confirm that while CE is a necessary salvage technique, its addition to standard CABG significantly extends both cardiopulmonary bypass and aortic cross-clamp times, inherently amplifying the overall operative complexity and requiring careful patient selection by experienced surgical teams. [16]

Table 1. Pathophysiological and mechanical challenges of performing CABG in stent-loaded coronary vessels.

Challenge Category	Underlying Mechanism	Clinical / Surgical Consequence	Ref.
Mechanical Constraints	Multiple stent layers, stent overlapping, or underexpansion.	Exhaustion of optimal ‘’landing zones” for bypass grafts; forces anastomosis in suboptimal segmants.	[6, 12]
Bilogical and Inflammatory	Neointimal hyperplasis and chronic inflammation induced by metallic stens.	Diffuse coronary artery disease; hostile biological environment for graft patency.	[12]
Procedural Injury	Disruption of epicardial plaques during PCI releasing atherothrombotic debris.	Endothelial dysfunction, vasoconstriction and patchy microinfarcts downstream.	[13]
Surgical Complexity	Heavily stented vessels requiring adjunctive salvage maneuvers.	Increased need for coronary endarterectomy; prolonged aortic cross-clamp and bypass times.	[14, 16]

3.4. The Impact of Multiple Prior PCIs

The impact of previous PCI on CABG outcomes is unclear. Furthermore, the significance of the number of previously performed PCI procedures remains a subject of ongoing clinical debate.

A meta-analysis of 21 comparative studies by Ueki et al., including 174,777 patients (of whom over 19,179 had undergone previous PCI), investigated this issue. The study demonstrated that the risk of hospital mortality significantly increased (OR: 1.187, 95% CI: 1.075–1.312) in cohorts of patients with a history of prior PCI. A subgroup analysis stratified by the percentage of multiple-PCI patients within the studies demonstrated a significant correlation. In studies where a large proportion (>40%) of patients had undergone multiple prior PCIs, a profound negative impact of these procedures was observed (OR: 1.987; 95% CI: 1.563–2.526). Moreover, a meta-regression analysis revealed a positive coefficient regarding the percentage of patients with multiple PCIs (coefficient: 0.841; 95% CI: 0.457–1.226; $p < 0.001$). This strongly suggests that repeated coronary stenting is associated with cumulative surgical risk and a consequent increase in postoperative mortality. These results also re-emphasize the importance of the multidisciplinary Heart Team in planning initial coronary revascularization. [17]

An adjusted analysis of a prospective multicenter registry by Biancari et al., comprising 2619 patients (of whom 420 had undergone a previous PCI), further investigated the impact of multiple PCIs on late mortality and major adverse cardiovascular and cerebral events. The study showed that patients with a history of multiple PCIs had a significantly higher risk of myocardial infarction and repeat revascularization at 5 years after CABG (SHR: 2.566, 95% CI: 1.379–4.312 and SHR: 1.774, 95% CI: 1.140–2.763, respectively). Similarly, the cohort of patients who had PCIs performed on multiple vessels exhibited a higher 5-year risk of myocardial infarction, repeat revascularization, and stroke (SHR: 2.640, 95% CI: 1.497–4.658; SHR: 1.648, 95% CI: 1.029–2.638; and SHR: 2.215, 95% CI: 1.056–4.646, respectively). However, it is important to highlight that in the group of patients who had undergone a prior single-vessel PCI, the risk of repeat revascularization was also elevated. Notably, multiple PCIs showed no correlation with increased early or late mortality, regardless of the number of treated vessels. [15]

The presence of multiple previously implanted metallic stents likely compromises the availability of optimal surgical targets for bypass grafting and intensifies the progression of local atherosclerosis, ultimately deteriorating the patient's long-term prognosis. It is important to emphasize that the negative outcomes of multiple PCIs were observed both in the group that had undergone multiple-vessel PCI and the group that had undergone single-vessel PCI. While a single prior percutaneous intervention may not drastically alter the surgical risk profile, a history of multiple PCIs emerges as a critical determinant of adverse late outcomes after CABG. However, as demonstrated by comparing these analyses, the literature remains inconsistent regarding the impact of multiple prior PCIs on early (postoperative) mortality.

Table 2. Summary of key meta-analyses and registries evaluating CABG outcomes in prior-PCI patients.

Study (Author, Year)	Study Type and Cohort Size	Follow-up	Key Findings regarding prior-PCI cohort	Ref.
Zhang et al. (2022)	Meta-analysis N = 308 284	1 to 13 years	Increasd risk of early all-cause mortality and early MACE. No significant impact no late mortality.	[9]
Mariscalco et al. (2018) (E-CABG Registry)	Prospective Registry N = 3 641	In-hospital	No significant increase of in-hospital mortality or major postoperative complications after prepensity matching.	[10]
Luthra et al. (2020)	Meta-analysis N = 218 063	Long-term	Comparable overall survival, but significantly higher rate of early and late MACE.	[11]
Bianciari et al. (2022)	Prospective	5 years	Multiple prior PCIs	[15]

	Registry N = 2 619		significantly increase the risk of late myocardial infarction and repeat revascularization.	
Ueki et al. (2015)	Meta-analysis N = 174 777	In-hospital	Significant increase of in-hospital mortality, with cumulative risk strongly correlated to the number of prior stents.	[17]

4. Discussion

The findings of this review highlight a clear clinical dichotomy: while prior PCI may not negatively affect long-term survival after subsequent CABG (as demonstrated by Luthra [11] and Zhang [9]), it undeniably complicates the surgical procedure and elevates the risk of early [11] and late MACE. [9, 11] This is particularly evident in patients with a history of multiple PCIs, who face a significantly higher risk of late myocardial infarction and repeat revascularization [15] and higher risk of hospital mortality. [17] This increased risk profile is intrinsically linked to the anatomical and pathophysiological challenges outlined previously. When patients receive multiple percutaneous interventions over time, the local vessel biology is permanently altered. As highlighted in the pathophysiological review by Wańha et al. [12], the chronic inflammatory state and endothelial dysfunction induced by metallic stent struts extend far beyond the stented segment itself. This creates a hostile biological environment for bypass grafts, theoretically increasing the risk of early graft failure and directly explaining the higher MACE rates observed in prior-PCI surgical cohorts.

Decisions regarding type of revascularisation should always be made by Heart Team, to prevent the phenomenon of the "stent-loaded" patient and the subsequent need for complex, high-risk salvage maneuvers such as coronary endarterectomy. [16] According to the foundational ESC/EACTS Guidelines on myocardial revascularization, the decision between PCI and CABG must not be made in isolation. Ad hoc stenting in stable patients with multivessel disease is not recommended and can cause the premature exhaustion of optimal surgical targets. [18] A recent joint ESC/EACTS review of the guidelines concludes that in patients with indications for revascularization due to left main (LM) coronary artery disease and suitable anatomy, both PCI and CABG are viable options. The choice should be based on the availability of local expertise and operator experience. Furthermore, the Task Force reiterates the importance of the multidisciplinary Heart Team in determining the revascularization strategy for this patient cohort. [19] Furthermore, modern analyses, including those derived from the ISCHEMIA trial, demonstrate that both revascularization strategies provide significant improvements in health status compared to the conservative management of chronic coronary disease. While CABG offers superior angina relief at 1 year compared to PCI, this clinical difference disappears at the 3-year follow-up. The study concludes that the invasive treatment of chronic coronary disease provides greater health status benefits than a conservative approach, regardless of the revascularization method utilized. [20]

The clinical penalty of prior percutaneous interventions is disproportionately higher in specific high-risk subgroups. Diabetic patients, who are inherently characterized by diffuse

atherosclerosis and small vessel disease, derive a well-documented survival benefit from primary CABG. Advanced studies evaluating long-term survival confirm that percutaneous interventions in multivessel diabetic patients can significantly increase long-term mortality and the risk of MACE. Furthermore, it is worth noting that repeat revascularization was significantly more frequent in the PCI group, with the risk being more than three-fold higher compared to the CABG cohort. Interestingly, the study demonstrated that only 10% of the patients who underwent PCI were ever consulted by a cardiac surgeon. This finding is highly concerning in light of the ESC/EACTS guidelines, which reiterate the importance of the multidisciplinary Heart Team approach in such cohorts. [21]

Additionally, in patients with severe left ventricular (LV) dysfunction, primary surgical revascularization remains the gold standard. The ESC/EACTS guidelines state that the ability to achieve complete revascularization should be a crucial factor when selecting the appropriate revascularization method. However, in specific groups of patients who are deemed unsuitable for surgery, PCI often remains the only viable strategy. Recent clinical consensus statements highlight that while high-risk PCI serves as an alternative for patients ineligible for surgery, achieving complete revascularization via percutaneous methods in this cohort is challenging. Incomplete PCI in patients with low ejection fractions is strongly associated with a higher risk of mortality and MACE. This underscores that while PCI can act as a salvage procedure in specific clinical scenarios, it is inherently associated with an elevated risk of adverse clinical outcomes. [22]

5. Conclusions

Patients undergoing coronary artery bypass grafting (CABG) after failed prior percutaneous coronary intervention (PCI) are a specific clinical cohort. This group is characterised by increased risk of early postoperative mortality and major adverse cardiovascular events. Surgical risk is even more significant in patients with a history of multiple stenting procedures. Studies demonstrate the negative cumulative effect of repeated percutaneous interventions on surgical outcomes and the availability of optimal bypass targets. Nevertheless, CABG remains a highly effective and definitive salvage strategy for patients with prior failed PCI. Studies prove its long-term outcomes are comparable to primary surgical revascularization. Therefore, a multidisciplinary Heart Team approach is necessary to evaluate percutaneous versus surgical options early in the treatment pathway, ensuring optimal patient qualification and preventing the exhaustion of surgical targets.

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Supplementary Materials
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