Journal of Cardiothoracic Surgery

RESEARCH

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Predictors of secondary revascularization after coronary artery bypass graft surgery and role of dual antiplatelet therapy

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Abstract

Background Despite advancements in surgical techniques, interventional procedures, novel pharmacotherapies, and other contemporary treatments, patients after coronary artery bypass graft surgery (CABG) remain at risk for graft failure and progression of native vessel disease progression. Consequently, secondary revascularization is often required.

Methods This is a retrospective observational study evaluating the incidence, trends, and predictors of revascularization after CABG surgery.

Results Of 2,476 patients followed in this post-CABG study, 1458 patients received dual antiplatelet therapy (DAPT) compared to 1005 patients received aspirin monotherapy (AMT). The overall incidence of revascularization was significantly higher in the DAPT group (14.54%, 212 out of 1458) compared to the AMT group (7.07%, 71 out of 1005), with an odds ratio (OR) of 2.24 (95% CI: 1.69–2.97, $p < 0.001$). 770 patients who received DAPT for six months or more after surgery were compared in sub-analysis and were noted to have significantly higher incidence of revascularization compared to AMT (22.08% vs. 6.96%; OR = 3.157, 95% CI: 2.734–4.940; $p < 0.001$). The binary regression model revealed that younger patients (hazard ratio (HR) = 0.964, 95% CI: 0.95–0.97; $p < 0.001$), diabetics (HR = 1.50, 95% CI: 1.12-2.00, $p = 0.007$), patients who had fewer internal mammary artery grafts (HR = 0.54, 95% CI: 0.36–0.81, $p = 0.003$), and patients receiving DAPT of any duration after CABG (HR = 3.47, 95% CI: 2.55–4.72, $p < 0.001$) were more likely to receive revascularization after CABG. The model, comprising these four predictors, was able to explain 12.8% of the variance in post-CABG revascularization (Nagelkerke $R^2 = 0.128$; $p < 0.001$). The survival rates were 96.5% for the DAPT group and 92.0% for AMT (odds ratio (OR) = 0.421, 95% confidence interval (95% CI): 0.269–0.658; $p < 0.001$).

Conclusion Diabetes mellitus, younger age, fewer Internal mammary artery grafts, and the use of DAPT after CABG were strong predictors of the need for secondary revascularization.

Keywords Dual Anti-platelet therapy, Secondary revascularization, Coronary artery bypass graft, Mortality

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Introduction

Background

Coronary artery disease (CAD) remains a leading cause of morbidity and mortality worldwide. Among the various treatment modalities for CAD, coronary artery bypass graft (CABG) surgery is widely regarded as the gold standard for treating patients with complex multivessel disease, offering superior clinical outcomes compared to non-surgical interventions [1].

Current knowledge

Achieving complete revascularization through CABG is associated with improved postoperative outcomes, a benefit not observed with percutaneous coronary intervention (PCI) [2]. Despite advancements in surgical techniques, interventional procedures, novel pharmacotherapies, and other contemporary treatments, patients' post-CABG remain at risk for graft failure and progression of native CAD [3, 4]. Consequently, secondary revascularization is often required, with PCI being the preferred method [4, 5]. Disease progression in native arteries is more frequently the cause of revascularization compared to graft failure [6, 7]. Several clinical and anatomic predictors have been identified as influential in secondary revascularization. Common anatomic factors include occluded grafts, total occlusion of native arteries, and the absence of internal mammary artery grafts [6]. Clinical predictors of secondary revascularization include previous myocardial infarction (MI), low ejection fraction, longer interval from CABG, younger age, female sex, pre-CABG dialysis, and previous PCI [7, 8]. Data from the Society of Thoracic Surgeons' National Adult Cardiac Surgery Database indicate cumulative incidences of secondary revascularization (PCI or CABG) at 1-, 5-, 10-, and 18-years post-surgery as 2%, 7%, 13%, and 16%, respectively, with repeat CABG rates remaining notably low at all time points [8].

Gaps in knowledge

While several clinical and anatomic predictors of secondary revascularization have been identified, including occluded grafts, total occlusion of native arteries, and absence of internal mammary artery (IMA) grafts, there is limited data on the impact of dual antiplatelet therapy (DAPT) on revascularization rates post-CABG. Additionally, the role of contemporary medical therapies in influencing these outcomes requires further investigation.

Rationale for the study

Secondary revascularization as an independent predictor of adverse outcomes such as death, stroke, and MI following initial PCI and CABG [9]. The need for secondary revascularization post-CABG is influenced by both clinical and anatomic factors. Given the high stakes associated with graft failure and the progression of native CAD, it is crucial to identify effective strategies to mitigate these risks. Antiplatelet therapy has shown benefits in reducing mortality, enhancing graft patency, and improving various clinical outcomes. However, its role in secondary revascularization remains unclear.

Aims and objectives

This study aims to evaluate the incidence, trends, and predictors of secondary revascularization post-CABG, with a particular focus on the impact of dual antiplatelet therapy (DAPT). By analyzing these factors, we seek to provide valuable insights that can inform clinical practice and guide future research. We plan to investigate the impact of DAPT post-CABG on the incidence of secondary revascularization compared to aspirin monotherapy (AMT). Additionally, we aim to identify other clinical and anatomic predictors of revascularization in this patient population.

Methods

Study design

This is a retrospective observational study evaluating the incidence, trends, and predictors of revascularization after CABG surgery at one of the large-volume open heart surgery centers in the United States. The focus was on assessing the impact of antiplatelet therapy, particularly DAPT, on revascularization rates. This study was approved by the hospital's executive medical committee and Institutional Review Board.

Participants

- **Inclusion and Exclusion Criteria**:

Inclusion criteria were:

1. Undergoing CABG surgery between 2012 and 2015.
2. Receiving either aspirin alone or aspirin in combination with P2Y12 antagonist referred to as DAPT at discharge.

Exclusion criteria were:

3. Death within the first 48 h post-surgery.
4. Requirement of anticoagulation therapy post-surgery.
5. Concomitant valve surgery.
6. Lost to follow up.

Group assignment

Patients who underwent CABG were included and assigned to the following two groups based on the antiplatelet therapy received at discharge: (1) AMT), or (2)

DAPT. DAPT was defined as patients receiving a combination of aspirin and a P2Y12 receptor antagonist post-CABG. The DAPT group (all durations) was compared to the AMT group, and a detailed subset analysis was performed for patients who received DAPT for six or more months, compared to those on AMT. The overall incidence of revascularization and secondary outcomes were evaluated in both groups using standard statistical methods.

Data collection

Data was manually collected from electronic medical records. Information was cross-checked by one of the investigators to ensure accuracy. Medical records from other hospitals and clinics were also reviewed thoroughly, and phone follow-ups were conducted to gather any missing information or clarify ambiguous clinical notes.

The data collected included patient demographics, comorbidities, surgical details, medication history, and post-CABG outcomes such as revascularization events and acute coronary syndrome (ACS) incidents.

Outcome measures

- **Primary Outcome**:

The primary outcome was the incidence of revascularization post-CABG, defined as any instance of PCI with or without stent placement, or redo CABG.

- **Secondary outcomes**:

1. Survival rate.
2. Major adverse cardiovascular events.
3. Post-CABG ACS.

- **Event Identification**:
  Revascularization events and ACS were identified using appropriate ICD codes, confirmed by EKG findings, and laboratory values. These events were systematically recorded and analyzed within each treatment group. MACE was composite of CV death, post-CABG ACS and CVA.

Statistical analysis

Descriptive statistics and frequencies were calculated for continuous and categorical variables. Group comparisons for continuous variables were conducted using appropriate statistical t-tests. Categorical variables were compared between groups using the Chi-Square test. Survival rates were compared using the Kaplan-Meier estimate. Logistic regression analyses were employed to investigate variables predictive of revascularization. Variables included in the models were selected based on clinical relevance and previous research. Hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated for each predictor. Statistical significance was set at a two-tailed p-value less than 0.05. All analyses were conducted using SPSS version 29.0 (IBM Corp., Armonk, NY).

Results

Patient demographics and baseline characteristics

Of the 2,476 patients included in this study, 1,458 received DAPT, while 1,005 were treated with AMT. Patients who died within the first 48 h post-CABG ($n = 12$) were excluded from the analysis.

Compared to those on DAPT, patients in the AMT group had a higher prevalence of chronic kidney disease (CKD) (18.8% vs. 14.1%; $p = 0.002$) and stable angina (65.6% vs. 60.6%; $p = 0.013$). In contrast, the DAPT group exhibited a higher prevalence of peripheral arterial disease (PAD) (14.8% vs. 10.5%; $p = 0.002$), glomerular filtration rate (GFR) < 60 (44.98% vs. 42.59%; $p = 0.020$), prior PCI (24.5% vs. 20.1%; $p = 0.011$), and pre-CABG use of DAPT (30.0% vs. 15.5%; $p < 0.001$). Additionally, patients in the DAPT group were more likely to undergo on-pump surgery (79.2% vs. 68.5%; $p < 0.001$) with a longer duration (210.15 vs. 185.66 min; $p < 0.001$).

Among the DAPT group, 770 patients received DAPT for ≥6 months. Compared to AMT, patients receiving prolonged DAPT were more likely to be female (31.7% vs. 24.3%; $p < 0.001$), younger (mean age 64.13 vs. 65.69 years; $p = 0.001$), and smokers (57.8% vs. 51.4%; $p = 0.007$). They also had a higher prevalence of co-morbidities, including COPD (27.2% vs. 25.1%; $p = 0.027$), PAD (18.2% vs. 10.5%; $p < 0.001$), prior MI (33.8% vs. 28.5%; $p = 0.018$), previous CVA (10.4% vs. 7.0%; $p = 0.010$), and prior PCI (28.8% vs. 20.1%; $p < 0.001$). DAPT patients were also more likely to have been prescribed P2Y12 antagonists prior to CABG (37.9% vs. 15.5%; $p < 0.001$) (for details, see Table 1).

Additionally, the DAPT group had a higher prescription rate of statins (90.7% vs. 86.6%; $p < 0.001$) and antiarrhythmic drugs (AAD) (33.3% vs. 22.6%; $p < 0.001$).

Revascularization rates

The overall incidence of revascularization was significantly higher in the DAPT group (14.54%, 212 out of 1458) compared to the AMT group (7.07%, 71 out of 1005), with an odds ratio of 2.24 (95% CI: 1.69–2.97, $p < 0.001$) (Table 2). In the first 2 years of follow up, revascularization occurred in 142 (9.7%) in the DAPT group versus 39 (3.9%) of the AMT group (OR = 2.512 95% CI: 1.780–3.548, $p < 0.001$). In the 2–5 years follow-up period, 68 (4.7%) in the DAPT group compared to 28 (2.8%) of the AMT group required post-CABG revascularization

Table 1 Baseline characteristics of patients

Variable	AMT (*N* = 1,005)	DAPT (*N* = 1,458)	DAPT ≥ 6 months (*N* = 770)	*p*-value
Age (Years)	65.67 ± 10.02	64.71 ± 10.02	64.13 ± 9.94	0.019
Sex (Male, *n*)	761 (75.8%)	1,060 (72.7%)	526 (68.3%)	0.086
Race/Ethnicity (*n*)				0.282
Caucasian	885 (88.1%)	1,255 (86.1%)	639 (83.0%)	
African American	32 (3.2%)	58 (4.0%)	42 (5.5%)	
Native American	37 (3.7%)	67 (4.6%)	40 (5.2%)	
Hispanic	25 (2.8%)	44 (3.0%)	30 (3.9%)	
Asian	13 (1.3%)	18 (1.2%)	9 (1.2%)	
Pacific Islander	1 (0.1%)	1 (0.1%)	0	
Multiple	2 (0.2%)	9 (0.6%)	6 (0.8%)	
Unknown	10 (1.0%)	6 (0.4%)	4 (0.5%)	
BMI (Kg/m2)	30.63 ± 5.78	30.75 ± 5.98	30.83 ± 5.87	0.620
Smoker (*n*)	516 (51.4%)	816 (56.1%)	445 (57.8%)	0.478
Co-morbidities (*n*)				0.007
Hypertension	873 (86.9%)	1,268 (87.0%)	670 (87.0%)	0.941
CVA	70 (7.0%)	131 (9.0%)	80 (10.4%)	0.072
COPD	253 (25.2%)	393 (27.0%)	230 (27.2%)	0.323
Hyperlipidemia	707 (70.3%)	1,029 (70.6%)	533 (69.2%)	0.903
Diabetes Mellitus	423 (42.1%)	583 (40.0%)	332 (43.1%)	0.297
CKD	189 (18.8%)	205 (14.1%)	114 (14.8%)	0.002
MI	287 (28.6%)	461 (31.6%)	260 (33.8%)	0.104
Stable Angina	659 (65.6%)	884 (60.6%)	487 (63.2%)	0.013
CHF	215 (21.4%)	302 (20.7%)	169 (21.9%)	0.684
PAD	106 (10.5%)	216 (14.8%)	140 (18.2%)	0.002
HbA1c (%)	6.63 ± 1.52	6.61 ± 1.51	6.71 ± 1.57	0.773
GFR > 60 ml/min/1.73 m^2 (*n*)	705 (70.2%)	1,052 (72.6%)	546 (71.2%)	0.208
GFR < 60 ml/min/1.73 m^2 (Avg)	42.59 ± 13.80	44.98 ± 13.11	45.09 ± 12.68	0.020
Ejection Fraction (%)	52.29 ± 11.55	54.44 ± 11.98	52.41 ± 11.96	< 0.001
Previous PCI/Stent (*n*)	202 (20.1%)	357 (24.5%)		0.011
PCI	188 (18.7%)	329 (22.6%)		0.021
Stent	107 (10.6%)	194 (13.3%)		0.048

Table 2 Revascularization– AMT versus DAPT

Follow-up Period	Revascularization (AMT)	Revascularization (DAPT)	*p*-value	OR	95% CI
< 2 years	39 (3.9%)	142 (9.7%)	< 0.001	2.512	1.780–3.548
2–5 years	28 (2.8%)	68 (4.7%)	0.018	1.676	1.087–2.577
Duration of Follow up	71 (7.07%)	212 (14.54%)	< 0.001	2.24	1.6–2.97

(OR = 1.676 (95% CI: 1.087–2.577, $p = 0.018$) (Figs. 1 and 2).

Among patients on AMT and those who received DAPT for more than six months after CABG, 240 out of 1775 patients(AMT=1005+DAPT=770, 13.51%) required revascularization during follow-up. A significantly higher incidence of revascularization was observed in the DAPT group compared to the AMT group (22.08% vs. 6.96%; OR = 3.157, 95% CI: 2.734–4.940, $p < 0.001$) (Table 3). In the first 2 years of follow-up, revascularization occurred in 116 (15.1%) of the DAPT ≥ 6 months group versus 39 (3.9%) of the AMT group (OR = 4.326, 95% CI: 3.049–6.140, $p < 0.001$), indicating a significantly higher risk of revascularization in patients receiving DAPT for at least 6 months. In the 2–5 years follow-up period, revascularization was reported in 51 (6.6%) of the DAPT ≥ 6 months group compared to 28 (2.8%) of the AMT group (OR = 2.393, 95% CI: 1.514–3.780, $p < 0.001$), reaffirming the increased risk of revascularization associated with prolonged DAPT use (Figs. 3 and 4).

Survival rates

The survival rates were 92.0% for AMT and 96.5% for the DAPT > 6 months group (odds ratio (OR) = 0.421, 95% confidence interval (95% CI): 0.269–0.658; $p < 0.001$(Fig. 5). Similarly, survival rate was significantly higher in overall DAPT group regardless of duration of treatment (96.16%) compared to the AMT group (92.14%) (OR = 0.47 95% CI: 0.33–0.67, $p < 0.001$. The incident rate of CV death (0.9% vs. 5.3%, OR = 0.165,

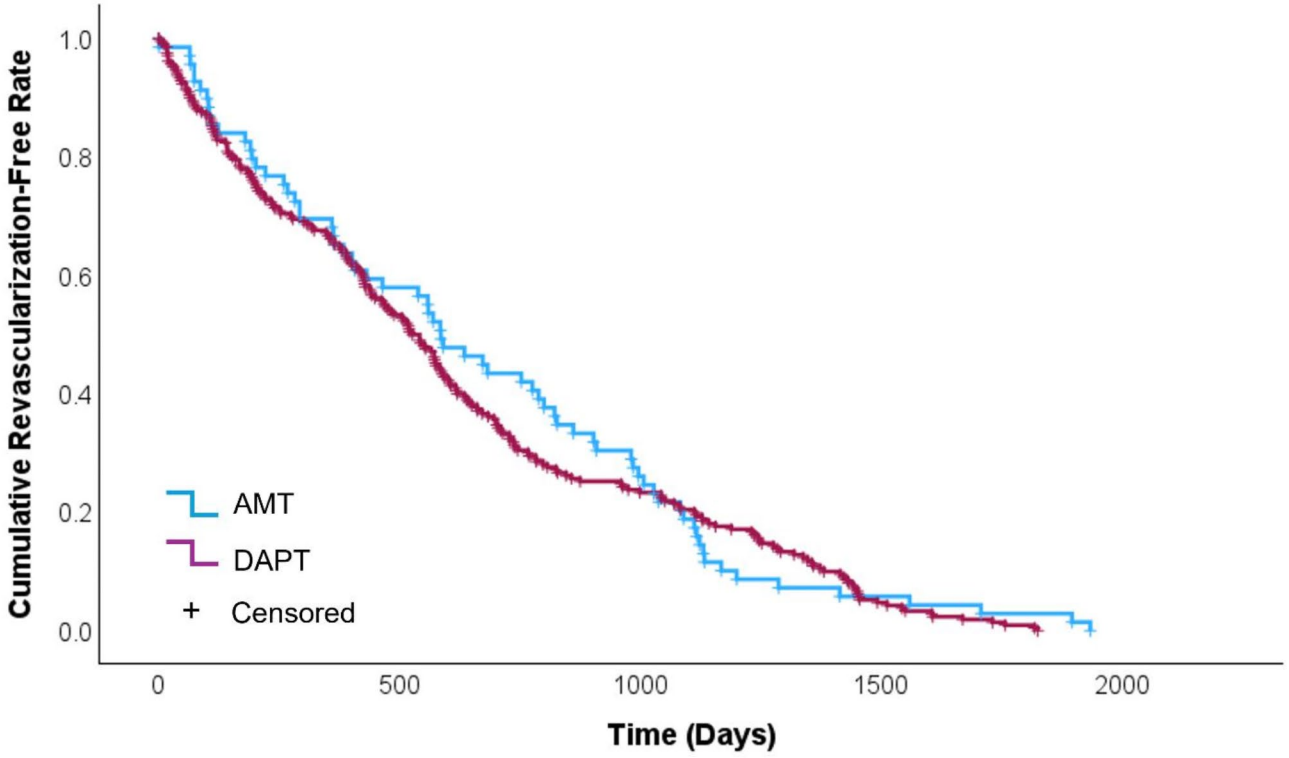

Fig. 1 Kaplan-Meier survival curves illustrating the **cumulative revascularization-free survival** in patients prescribed **DAPT** compared to those receiving **AMT** throughout the entire follow-up duration. The **AMT group** (blue) shows a relatively higher revascularization-free survival compared to the **DAPT group** (purple). "+" indicates **censored patients** who were lost to follow-up or did not experience revascularization by the end of the study

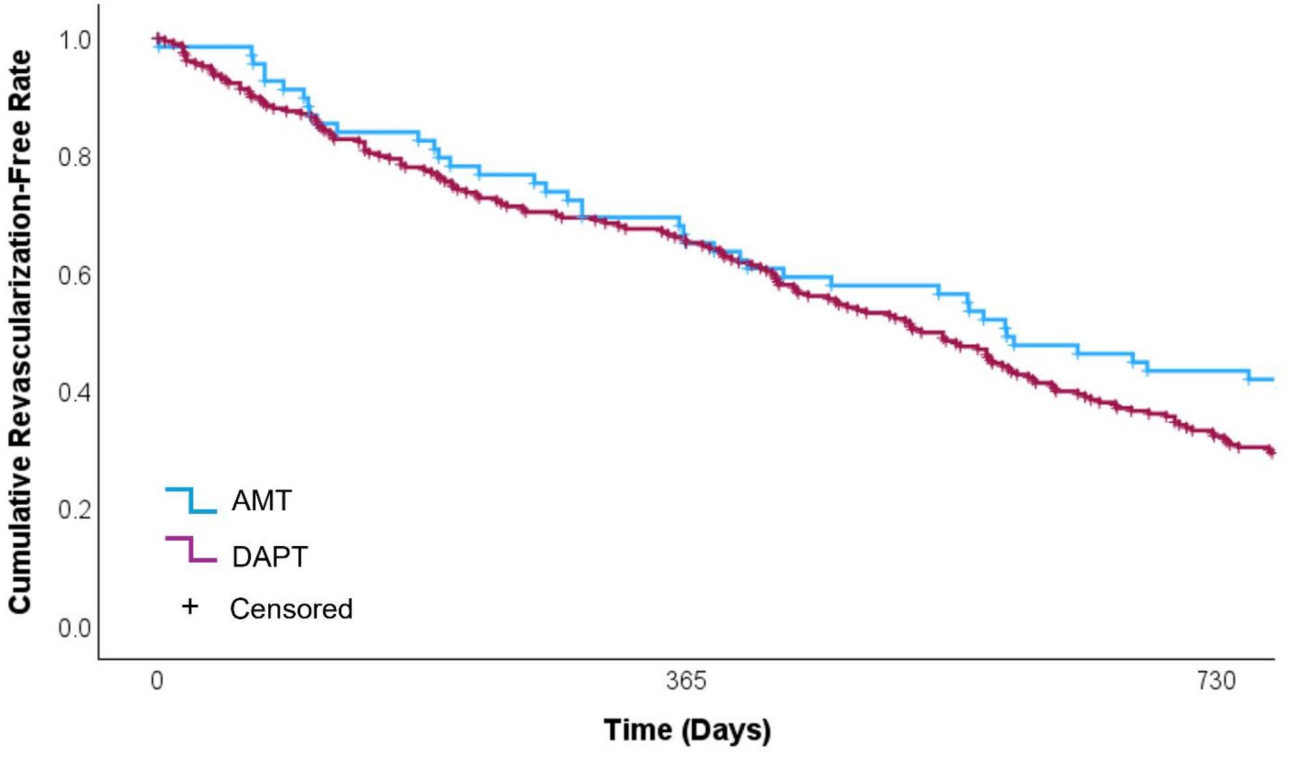

Fig. 2 Kaplan-Meier survival curves depicting cumulative revascularization-free survival in patients treated with **DAPT** versus **AMT** during the first two years post-surgery. The **AMT group** (blue) demonstrates a higher revascularization-free survival rate compared to the **DAPT group** (purple)

Table 3 Revascularization occurrence (AMT vs. DAPT ≥ 6 months)

Follow-up Period	Revascularization (AMT)	Revascularization (DAPT ≥ 6 months)	*p*-value	OR	95% CI
< 2 years	39 (3.9%)	116 (15.1%)	< 0.001	4.326	3.049–6.140
2–5 years	28 (2.8%)	51 (6.6%)	< 0.001	2.393	1.514–3.780
Total Duration of Follow up	70 (6.96%)	170 (22.08%)	< 0.001	3.15	2.73–4.94

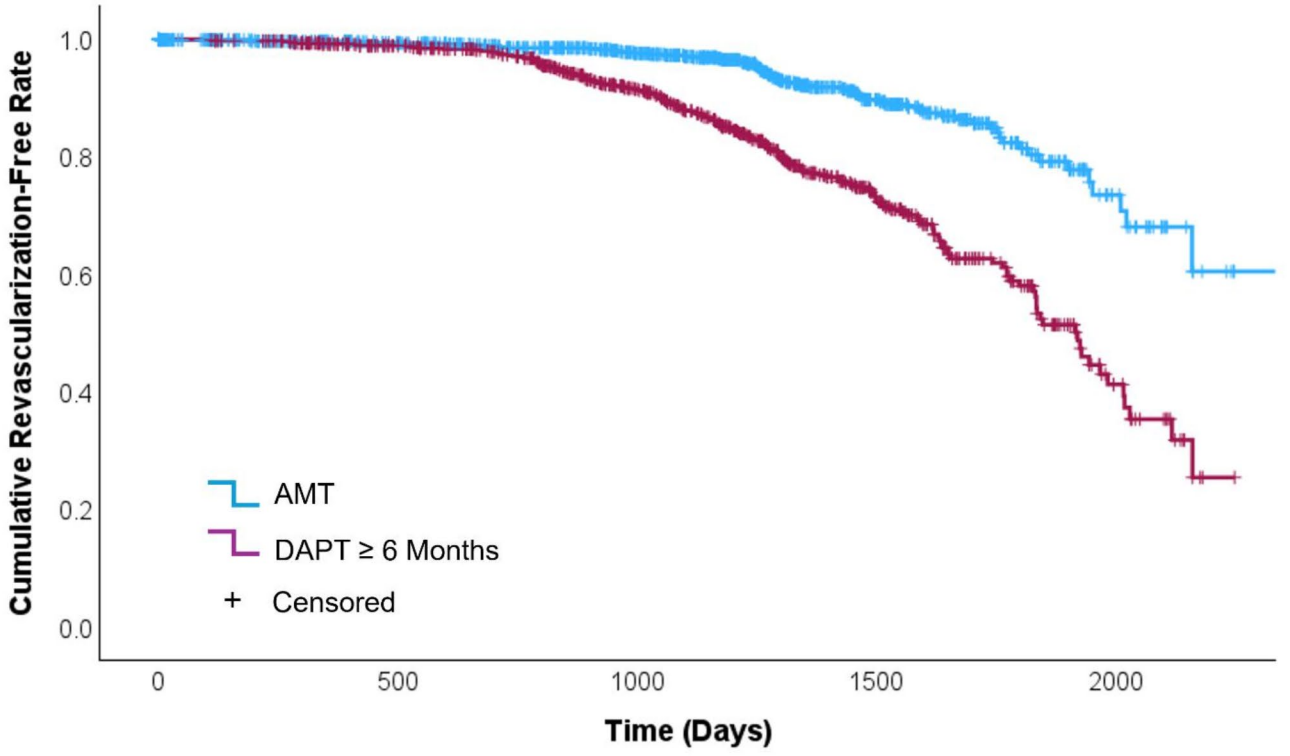

Fig. 3 Kaplan-Meier survival curves illustrating the **cumulative revascularization-free survival** in patients prescribed **DAPT > 6 months** compared to those receiving **AMT** throughout the entire follow-up duration. The **AMT group** (blue) demonstrates a higher revascularization-free survival rate compared to the **DAPT group** (purple)

95%CI: 0.075–0.366; $p < 0.001$) was both lower in the DAPT > 6 months group and DAPT group all durations compared to AMT (OR = 0.27 (95% CI: 0.16–0.45, $p < 0.001$).

Secondary outcomes

The incidence of post-CABG ACS was 4.18% in the AMT group and 5.69% in the DAPT group, regardless of treatment duration, with similar odds (OR: 1.38, 95% CI: 0.95–2.02, $p = 0.11$).

However, there was a significantly higher rate of post-CABG ACS events in the DAPT group receiving greater than six months treatment, compared to the AMT group (8.1% vs. 3.9%; OR = 2.172, 95% CI: 1.439–3.281; $p < 0.001$). Of note, there was no significant difference in the rate of major adverse cardiovascular events (MACE) between the DAPT group (12%) and the AMT group (11%) (OR = 2.172, 95% CI, $p = 1.097$). Patients presenting with ACS prior to CABG were significantly more likely to experience post-CABG ACS events (7.1%) compared to those undergoing elective CABG (4.0%) (OR = 1.834, 95% CI, $p = 0.002$).

Regression model findings

The binary regression model revealed that younger patients (HR = 0.964, 95% CI: 0.95–0.97; $p < 0.001$), diabetics (HR = 1.50, 95% CI: 1.12-2.00, $p = 0.007$), patients who had fewer internal mammary artery(IMA) grafts (HR = 0.54, 95% CI: 0.36–0.81, $p = 0.003$), and patients receiving DAPT after CABG (HR = 3.47, 95% CI: 2.55–4.72, $p < 0.001$) were more likely to receive revascularization after CABG (Table 4). The model, comprising these four predictors, was able to explain 12.8% of the variance in post-CABG revascularization (Nagelkerke $R^2 = 0.128$; $p < 0.001$).

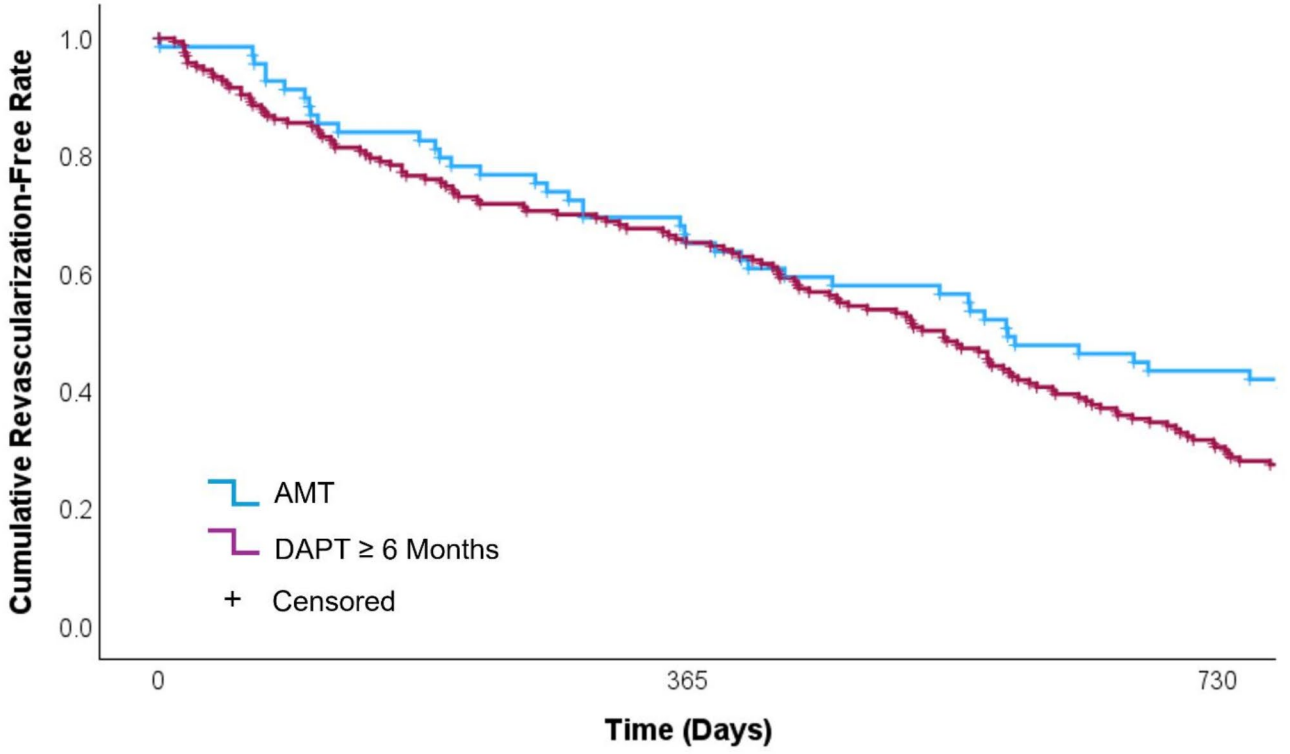

Fig. 4 Kaplan-Meier survival curves illustrating the **revascularization-free survival** in patients prescribed **DAPT > 6 months** compared to those receiving **AMT** in the first two years post-srugery. The **AMT group** (blue) demonstrates a higher revascularization-free survival rate compared to the **DAPT group** (purple)

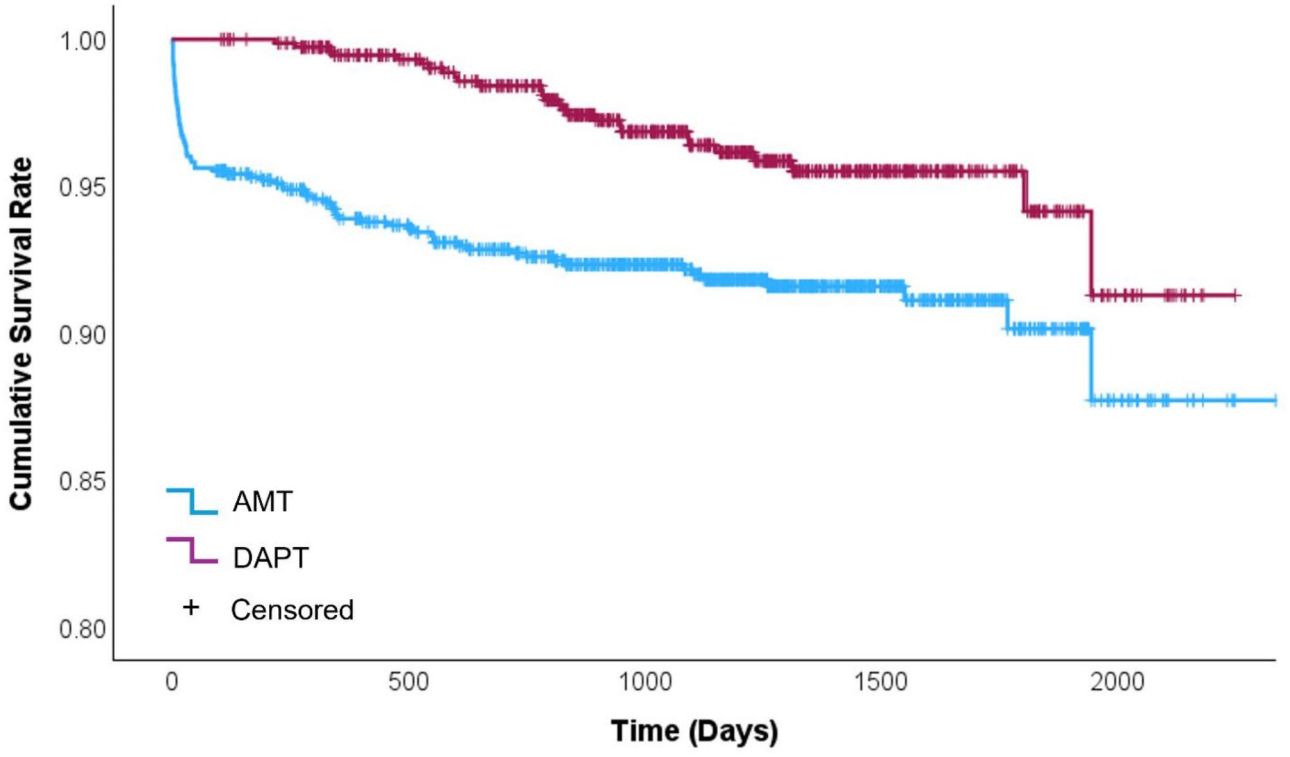

Fig. 5 Kaplan-Meier survival curves illustrating **survival** in patients prescribed **DAPT > 6 months** compared to those receiving **AMT** throughout the entire follow-up duration. The **AMT group** (blue) demonstrates a higher revascularization-free survival rate compared to the **DAPT group** (purple)

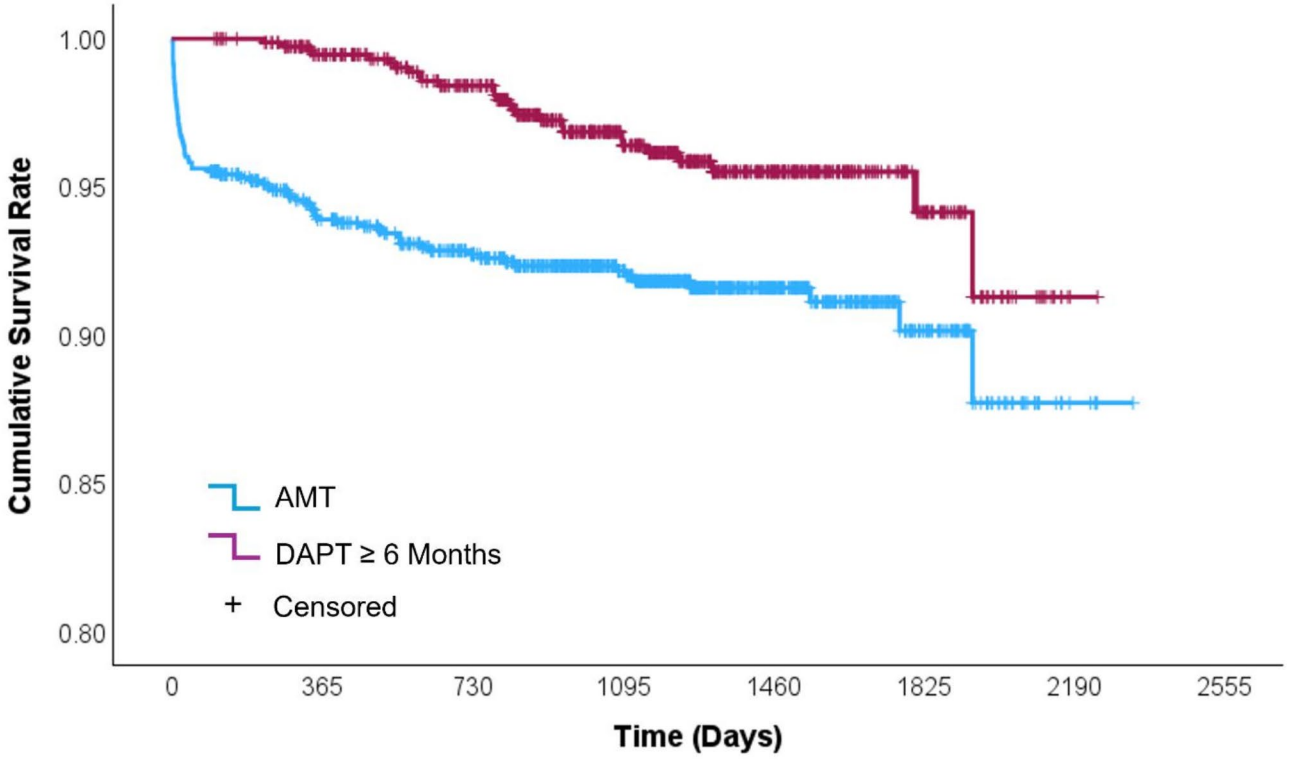

Fig. 6 Kaplan-Meier survival curves illustrating **survival** in patients prescribed **DAPT** compared to those receiving **AMT** throughout the entire follow-up duration. The **AMT group** (blue) demonstrates a higher revascularization-free survival rate compared to the **DAPT group** (purple)

Table 4 Pre- and Post-CABG medications and surgical variables in AMT vs. DAPT groups

Variable	AMT (*N*)	DAPT (*N*)	*p*-value
Pre-CABG Medications (*n*)			
ASA	682 (67.9%)	1,031 (70.8%)	0.118
P2Y12 receptor antagonist	156 (15.5%)	437 (30.0%)	< 0.001
Surgical Variables			
On-Pump surgery (*n*)	679 (68.5%)	1,124 (79.2%)	< 0.001
Surgery duration (min)	185.66 ± 55.87	210.15 ± 70.27	< 0.001
SV Graft	2.28 ± 1.00	2.07 ± 1.00	< 0.001
LIMA grafts	0.94 ± 0.28	0.89 ± 0.36	**< 0.001**
Radial Artery grafts	0.01 ± 0.11	0.02 ± 0.14	0.238
Post-CABG Medications (*n*)			
BB	887 (88.3%)	1,273 (87.3%)	0.482
ACE-I/ARB	531 (52.8%)	837 (57.4%)	0.025
AAD	227 (22.6%)	485 (33.3%)	< 0.001
CCB	165 (16.4%)	277 (19.0%)	0.101
Statin	870 (86.6%)	1,322 (90.7%)	0.001

Values are *n* (%) or *n*, unless otherwise indicated.

AMT = aspirin monotherapy; DAPT = dual antiplatelet therapy; BMI = body mass index; CVA = cerebrovascular accident; COPD = chronic obstructive pulmonary disease; CKD = chronic kidney disease; MI = myocardial infarction; CHF = congestive heart failure; PAD = peripheral arterial disease; GFR = glomerular filtration rate; PCI = percutaneous coronary intervention; CABG = coronary artery bypass graft; ASA = aspirin; BB = beta-blocker; ACE-I = angiotensin converting enzyme inhibitor; ARB = angiotensin receptor blocker; AAD = antiarrhythmic drugs; CCB = calcium channel blocker; LIMA = left internal mammary artery; SV = saphenous vein

Discussion

The findings from this post-CABG study highlight several key demographic, survival, and revascularization outcomes associated with DAPT versus AMT in patients after CABG.

Patient demographics and baseline characteristics

The DAPT group generally consisted of younger patients, females, and those with higher risk factors, including smoking, CKD, COPD, and a history of ACS, PAD, CVA, or previous PCI. These patients were more likely to have been on DAPT prior to CABG, indicating a population with greater baseline cardiovascular risk compared to those receiving AMT. Details of these differences are discussed in the next section.

Survival and revascularization after CABG

A total of 13.51% of patients required revascularization during follow-up, with DAPT patients exhibiting a higher rate of revascularization (22.08%) compared to the AMT group (6.96%, $p < 0.001$). Although this study primarily focused on patients who received DAPT for six months or more after CABG, we observed a higher incidence of revascularization in the DAPT group compared to the AMT group, irrespective of the duration of DAPT treatment (see supplementary data). This finding indicates that, despite the observed survival advantage, the DAPT group may have experienced a higher need for subsequent revascularization, driven by multiple potential factors that warrant further in-depth analysis. First, DAPT patients exhibited significantly higher-risk characteristics, such as prior MI, pre-CABG PCI, and PAD, making them more susceptible to secondary revascularization. Second, DAPT appears to offer a survival benefit for patients who have experienced ischemic coronary events and has led to an increased need for secondary revascularization. In contrast, ischemic events in the AMT group were more likely to result in fatal outcomes, contributing to their higher mortality rate and therefore lower incidence of secondary revascularization. Finally, the fewer grafts in the DAPT group might also suggest incomplete revascularization during CABG, potentially leading to subsequent PCI for untreated lesions and may have been a planned hybrid approach in these patients. Since this study did not collect data on anticipated PCI post-CABG, we were unable to differentiate between planned and unanticipated revascularization, which may have resulted in an overestimation of unanticipated revascularization rates in the DAPT group. In nutshell, higher revascularization rates in the DAPT group may reflect improved survival, suggesting that revascularization itself could be a beneficial outcome rather than solely an adverse event. Additionally, the lower revascularization rate in the AMT group may indicate a higher incidence of fatal MI, implying that patients on DAPT were more likely to survive an MI post-CABG compared to those on AMT.

Despite these limitations, our findings highlight several critical aspects relevant to secondary revascularization following CABG. The survival benefit of DAPT is likely attributed primarily to its ability to prevent thrombotic occlusion of grafts during the initial months following CABG (see Fig. 1), with some contribution potentially related to maintaining graft patency. Despite greater cardiovascular risk and higher burden of comorbidities, DAPT group demonstrated a survival benefit, with a higher survival rate of 96.5% compared to 92.0% in the AMT group ($p < 0.001$). In contrast, revascularization appears to be more closely associated with the progression of native vessel disease or overall atherosclerosis, areas where DAPT may have a limited preventive role.

Secondary outcomes

The incidence of post-CABG acute coronary syndrome (ACS) was slightly higher in the DAPT group compared to AMT (5.69% vs. 4.18%), though this difference did not reach statistical significance (OR: 1.38, 95% CI: 0.95–2.02, $p = 0.11$), suggesting that, overall, DAPT did not markedly increase the risk of post-CABG ACS. However, when stratified by treatment duration, a significant association emerged. Patients receiving DAPT for more than six months had a more than twofold increased risk of post-CABG ACS compared to those on AMT (8.1% vs. 3.9%; OR = 2.172, 95% CI: 1.439–3.281; $p < 0.001$). But of note there was no significant difference in overall MACE rates between the two groups. This difference may be attributed to higher baseline cardiovascular risk, including previous MI, PCI, PAD, CKD, and COPD. Additionally, the DAPT group had a higher prevalence of pre-CABG stents, pre-CABG DAPT prescriptions, and received fewer grafts during CABG compared to the AMT group. These factors likely placed the DAPT group at greater risk for post-CABG ischemic events necessitating revascularization. Notably, patients who underwent urgent CABG had a significantly higher incidence of post-CABG ACS compared to those who had elective procedures (7.1% vs. 4.0%; OR = 1.834, $p = 0.002$). Alternatively, the increased ACS rate in the DAPT ≥ 6 months group might also reflect improved survival, wherein these patients were more likely to survive an initial ischemic event and subsequently develop ACS requiring intervention. In contrast, patients in the AMT group may have suffered more fatal ischemic events, resulting in an underestimation of their ACS burden. Further investigation is warranted to determine whether prolonged DAPT contributes to a net clinical benefit or whether a more selective approach to DAPT duration should be considered in the post-CABG setting.

Table 5 Predictors of revascularization after CABG

Variables	Hazard Ratio	95% CI for Exp (B)	*p*-value
Age	0.962	0.948–0.976	< 0.001
Diabetes	1.494	1.116–1.998	0.007
LIMA	0.543	0.364–0.810	0.003
Post-CABG P2Y12 Antagonists	3.466	2.547–4.718	< 0.001

Regression model findings

The regression analysis identified younger age, diabetes, fewer IMA grafts, and post-CABG DAPT use as predictors of revascularization, accounting for 12.8% of the variance in revascularization outcomes (Nagelkerke $R^2 = 0.128$, $p < 0.001$) (Table 5). Notably, DAPT use after CABG emerged as the strongest predictor of revascularization, aligning with the observed increased rates of intervention in this cohort. While our findings aligned with some of the clinical and anatomic predictors of revascularization reported previously, including younger age, diabetics and fewer IMA grafts. We didn't observe some of the reported predictors like history of MI, multivessel disease, previous PCI or surgical indications as predictors of revascularization after CABG.

In clinical decision-making, older patients require a more cautious approach due to their elevated risk profile, often necessitating careful selection between PCI and medical therapy to minimize complications, particularly bleeding [9]. These age-related risks emphasize the importance of tailored revascularization strategies to optimize outcomes based on patient age and health status [10]. Diabetic patients, due to factors like endothelial dysfunction and heightened inflammatory response, also face a greater likelihood of progressive vessel disease and restenosis, increasing the need for additional revascularization, such as redo-CABG or PCI, to manage symptoms effectively [9, 11, 12]. Moreover, the use of arterial grafts, particularly IMA grafts, has been associated with improved long-term outcomes, including lower mortality and reduced incidence of (MACE, myocardial infarction, and secondary revascularization. IMA grafts, especially those bypassing the left anterior descending artery, demonstrate superior durability and resistance to atherosclerosis compared to saphenous vein grafts (SVG), which are more susceptible to occlusion [13]. While studies on DAPT's role in reducing revascularization after CABG are limited, small randomized controlled trials have shown DAPT's efficacy in maintaining graft patency, although its effect on secondary revascularization remains inconclusive due to small sample sizes and limited power [14–16]. DAPT has demonstrated clinical utility in CABG patients with ACS [17–20] and may also be beneficial in high-risk cases where ischemic risk exceeds bleeding risk, but overall, low-dose aspirin remains the primary antithrombotic therapy post-CABG. DAPT's role in improving survival and decreasing adverse outcomes is evolving, though its impact on reducing revascularization remains unsubstantiated in both small trials and large observational studies (21–22).

Surgical indications

Although there was a significant baseline difference in surgical indications between groups, the regression model did not identify this factor as a predictor for post-CABG revascularization. For instance, multivessel disease was more prevalent in the AMT group (29.1%) compared to the DAPT group (25.7%; $p = 0.026$), but this did not emerge as a significant predictor in the regression model (Table 3).

Limitations

This study's retrospective design and single-center setting may limit the generalizability of the findings. Additionally, the observational nature precludes establishing a direct cause-and-effect relationship between DAPT and revascularization. While we found an increased drop in hemoglobin in the DAPT group, transfusion requirements and major bleeding events (e.g., intracranial bleeding) were similar between groups. These results have been presented in different other articles by authors.

Future research should focus on large-scale, randomized controlled trials to elucidate the causal relationship between DAPT and revascularization post-CABG. Investigating the underlying mechanisms and patient-specific factors that influence these outcomes will be crucial for developing tailored therapeutic strategies.

Conclusion

While there is no established cause-and-effect relationship with DAPT therapy in this context, it is plausible to assert that the improved survival and the higher burden of cardiovascular risk factors (previous PCI, h/o MI, COPD, CKD and ACS presentation) in patients receiving DAPT post-CABG are the primary reasons for the increased revascularization rate in this patient population. Secondary preventative therapies should continue to focus on controlling cardiovascular risk factors (i.e. diabetes) and rehabilitation targeting to halt progression of atherosclerosis to minimize the need for revascularization after CABG.

Abbreviations

CABG Coronary artery bypass graft
DAPT Dual antiplatelet therapy

AMT	Aspirin monotherapy
ACS	Acute coronary syndrome
CV	Cardiovascular
OR	Odds ratio
CI	Confidence interval
PCI	Percutaneous coronary intervention
IRB	Institutional review board
RCT	Randomized controlled trial

Author contributions
Each author contributed significantly to the conception, design, execution, or analysis of the research described in this article. The specific contributions of each author are outlined as follows: Iftikhar Ch: Conceptualization, methodology, investigation, manuscript writing, data analysis and presentation. "Khurram Nasir, Naeem Tahirkheli: Supervision, validation, writing– review and editing." Azhar Chaudhry, Muhammad Siddique: Manuscript writing, data analysis and discussion. Pei-Tzu Wu: Data management, statistical analysis, manuscript writing and formatting. Raja Ullah, Abdul Qadar, Hunter Weitzel, Rahat Jamal, Mashal Tahirkheli: Data management, chart review, consenting, maintaining proper records, formatting, and manuscript writing. Additionally, all authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding
None.

Data availability
The data that support the findings of this study are available [upon request/ from the corresponding author/in the supplementary material]. Restrictions apply to the availability of these data, which were used under license for the current study and are not publicly available. However, the data are available from the authors upon reasonable request and with permission from Oklahoma Heart Hospital. Any additional data related to this study will be made available in accordance with journal policies and upon request.

Declarations

Conflict of interest/Disclosure
Dr Khurram Nasir MD: CONSULTING FEES/HONORARIA: Amgen Inc. (SIGNIFICANT), Esperion(MODEST), Novartis Corporation(MODEST), Novo Nordisk Inc.(SIGNIFICANT) SPEAKER'S BUREAU: Amgen Inc.(MODEST). All other authors: None.

Ethics statement
This ethics statement affirms that the research adhered to the highest ethical standards and guidelines established by regulatory bodies. Informed consent was obtained from the participants, confidentiality and privacy of participant information were maintained, conflicts of interest are denied, high morals were upheld, data integrity and transparency were ensured, authorship criteria were outlined, and contributions were acknowledged appropriately.

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Received: 8 November 2024 / Accepted: 6 April 2025
Published online: 16 April 2025

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