7-20-2022

Trends and Outcomes of Myocardial Infarction in Patients With Previous Coronary Artery Bypass Surgery

Michael Megaly

Ramy Sedhom

Ayman Elbadawi

Kevin Buda

Mir B. Basir

See next page for additional authors

Authors

Michael Megaly, Ramy Sedhom, Ayman Elbadawi, Kevin Buda, Mir B. Basir, Santiago Garcia, Emmanouil S. Brilakis, Stephane Rinfret, and Khaldoon Alaswad

Trends and Outcomes of Myocardial Infarction in Patients With Previous Coronary Artery Bypass Surgery

Michael Megaly, MD, MS[a], Ramy Sedhom, MD[b], Ayman Elbadawi, MD[c], Kevin Buda, DO[d], Mir B. Basir, DO[a], Santiago Garcia, MD[e], Emmanouil S. Brilakis, MD, PhD[e], Stephane Rinfret, MD, SM[f], and Khaldoon Alaswad, MD[a,*]

Data on myocardial infarction (MI) treatment in patients with previous coronary artery bypass grafting (CABG) is limited. We queried the Nationwide Readmissions Database to identify hospitalizations of patients with MI from 2016 to 2019. Among hospitalized patients presenting with MI, 10.3% had previous CABG. Patients with MI who had previous CABG were less likely to be revascularized than those without previous CABG for both ST-segment elevation MI (STEMI) (46.4% vs 68.4%) and non-ST-segment elevation MI (NSTEMI) (30.8% vs 36.7%). CABG was associated with a lower risk of death in NSTEMI patients (odds ratio [OR] 0.84, 95% confidence interval [CI] 0.82 to 0.86), but a higher risk in STEMI patients (OR 1.06, 95% CI 1.01 to 1.13). Revascularization was associated with a lower risk of in-hospital death in patients with previous CABG presenting with STEMI (OR 0.30, 95% CI 0.26 to 0.35) and NSTEMI (OR 0.21, 95% CI 0.19 to 0.23). **(Am J Cardiol 2022;00:1−7)**

Introduction

Coronary artery bypass grafting (CABG) is a commonly used revascularization strategy for managing complex coronary artery disease (CAD) based on multiple trials.[1,2] Although percutaneous coronary intervention (PCI) has proven to be an acceptable alternative in certain complex disease subsets, including left main CAD[3] and less complex multivessel CAD,[4] CABG remains the preferred treatment for highly complex CAD. However, patients who undergo CABG remain at risk of native CAD progression and bypass graft (especially saphenous vein graft [SVG)] failure.[5] Moreover, rates of graft failure, which can present as progressive angina[6] and acute myocardial infarction (MI),[7,8] can be as high as 40% for SVGs and 15% for internal mammary artery (IMA) grafts at 10 years.[9,10]

Contemporary data on the outcomes of patients with previous CABG who present with MI are limited, and recent trends in the United States have not been described. We aimed to identify the contemporary trends and outcomes of these patients in the US utilizing the Nationwide Readmissions Database (NRD) from 2016 to 2019.

Methods

We used the NRD Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, to obtain our cohort.[11] The NRD contains discharge data from 28 geographically dispersed US states, accounting for 60% of the total US resident population and 58.2% of all US hospitalizations. We identified our cohort, procedures, and outcomes using the International Classification of Diseases, Tenth Revision (ICD-10), Clinical Modification and ICD-10, Procedure codes. The codes and definitions used are listed in Supplementary Table 1.

We identified our cohort using the ICD-10 codes from January 2016 to December 2019. Patient- and hospital-level variables provided by HCUP were used to identify demographics and baseline characteristics. Comorbidities and outcomes were identified using appropriate ICD-10, Clinical Modification and ICD-10, Procedure codes. Codes for MI and previous CABG in HCUP administrative databases have been previously utilized.[12,13] We excluded patients with missing in-hospital mortality data. The NRD is a publicly available database with de-identified hospitalization records; therefore, institutional review board approval was not required.

Given the differences in patients' characteristics and management between patients with ST-segment elevation MI (STEMI) and those with non-STEMI (NSTEMI), we analyzed these subgroups separately in our analysis. The primary outcomes of our study were to identify trends of admissions and revascularization and in-hospital mortality of patients with previous CABG who presented with MI. Secondary outcomes included discharge to a nursing facility, urgent readmission, hospital length of stay, and the index hospitalization cost. Major complications included major bleeding, major amputation, and renal and cerebrovascular complications.

[a]Division of Cardiology, Henry Ford Hospital, Detroit, Michigan; [b]Department of Medicine, Albert Einstein Medical Center, Philadelphia, Pennsylvania; [c]Section of Cardiology, Baylor College of Medicine, Houston, Texas; [d]Department of Internal Medicine, Hennepin Healthcare, Minneapolis, Minnesota; [e]Minneapolis Heart Institute at Abbott Northwestern Hospital, Minneapolis, Minnesota; and [f]Division of Cardiology, Emory University, Atlanta, Georgia. Manuscript received March 17, 2022; revised manuscript received and accepted June 6, 2022.

See page 6 for disclosure information.

*Corresponding author: Tel: 313-916-2600; Fax: 313.916.3917.
E-mail address: Kalaswa1@hfhs.org (K. Alaswad).

0002-9149/
https://doi.org/10.1016/j.amjcard.2022.06.002

Analyses of national estimates and logistic regression were conducted using the appropriate weighting, stratifying, and clustering of samples, following HCUP regulations.[14,15] Categorical variables are displayed as numbers and percentages. Continuous variables are presented as medians with interquartile ranges (25th to 75th percentile). All trend analyses were performed using Poisson regression. All p values are 2-sided with a significance threshold of <0.05. Given the very large sample size, we elected not to perform pairwise statistical comparisons, but rather to focus on the absolute numbers and their clinical significance. We considered a 5% relative difference between groups to be potentially clinically relevant.

We performed multivariable logistic regression analyses using the enter method to identify variables associated with in-hospital mortality. We included all variables considered significant based on background knowledge. We did not perform propensity score matching for outcomes differences between the CABG and no-CABG groups, given the limitations of the administrative database's variables and the risk of unmeasured bias. Statistical analysis was performed using STATA version 17.0 for Windows (StataCorp LLC, College Station, Texas).

Results

The flowchart of the study is shown in Figure 1. Our final cohort included patients who had previous CABG and presented with MI (214,975 records representing a national estimate of 397,753 patients). Those patients accounted for 10.3% of patients who presented with MI throughout the study period, with a 10% decrease across the study period (11.1% in the first quarter of 2016 to 10.2% in the last quarter of 2019) (Figure 2).

Among patients with previous CABG, 11.8% had STEMI, whereas 88.7% had NSTEMI (0.5% had both diagnoses during the same hospitalization). Over the study period, patients with previous CABG had a significant (44%) increase in the trend for presenting with STEMI (9.6% in the first quarter of 2016 to 13.9% in the last quarter of 2019) and a decrease in that with NSTEMI (90.8% to 86.7%) (Figure 3). Among patients who presented with MI, 43.1% were revascularized (84.4% with PCI, 16.8% with CABG, and 1.2% with both). Among patients with previous CABG, only 32.5% were revascularized (88.5% with PCI, 12.7% with redo CABG, and 1.1% with both).

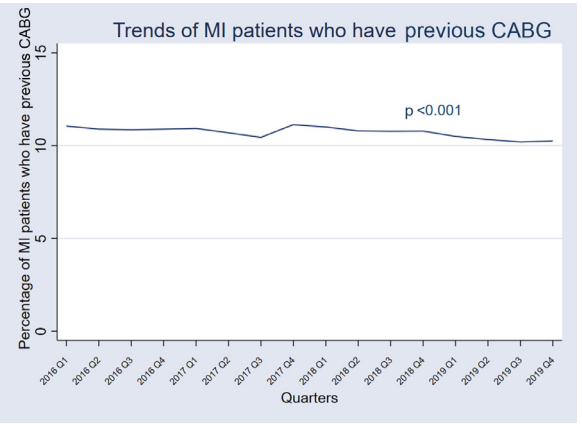

Figure 2. The trend of admissions of patients with MI who had previous CABG. Q = quarter.

Differences in baseline characteristics and outcomes in patients with previous CABG who presented with STEMI vs NSTEMI are listed in Table 1**.** Patients with previous CABG who presented with NSTEMI were older (median age 74 vs 71 years), more likely to be women (29.7% vs 24.8%), and had more comorbidities. They had slightly lower incidence of in-hospital mortality (6.8% vs 8.8%), lower incidence of urgent readmission (4.3% vs 7%), lower incidence of cardiogenic shock (4.2%, vs. 10.8%), and lower cost of admission ($14,633 vs. $18,019).

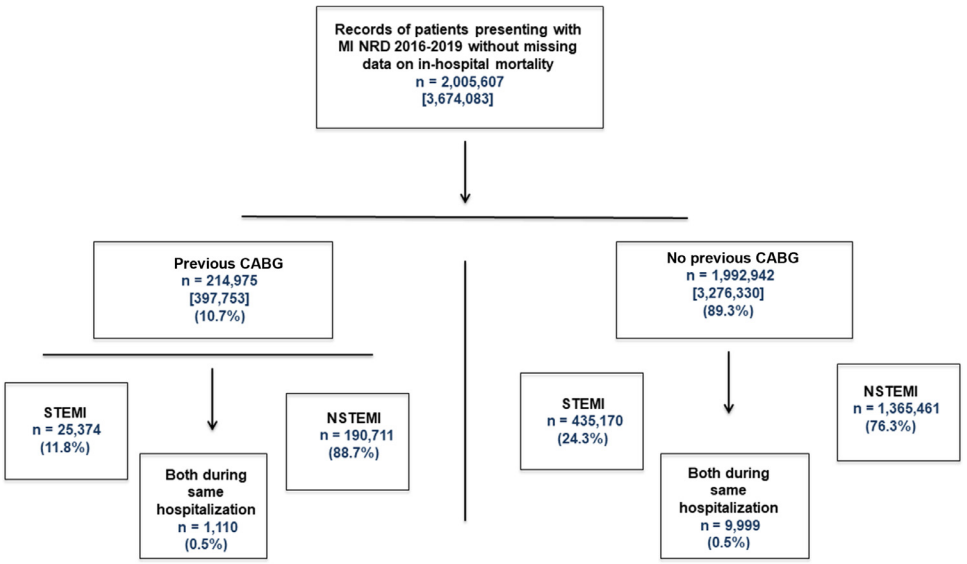

Figure 1. Flowchart of the study. Numbers between square brackets represent the national estimate of the respective cohort.

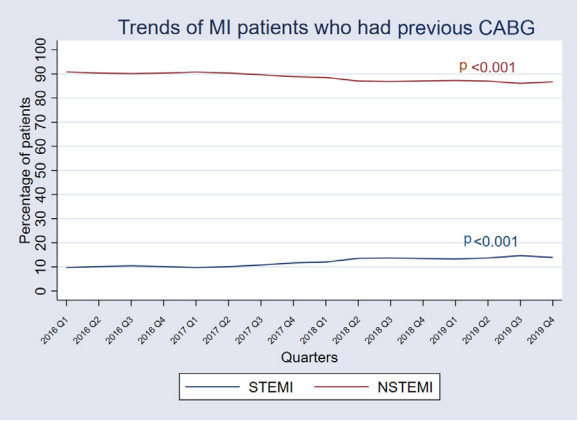

Figure 3. Trends of patients with previous CABG who presented with myocardial infarction, according to type of myocardial infarction. Q = quarter.

During the study period, a total of 449,435 patients presented with STEMI (accounting for a national estimate of 832,877 patients). Of those, 5.5% had a history of CABG. Differences in baseline characteristics and outcomes between patients with STEMI who had previous CABG and those who did not are listed in Table 2. Among patients who presented with STEMI during the study period, patients with previous CABG were significantly older (age 71 vs 64 years), less likely to be women (24.8% vs 32.6%), had more comorbidities, and had a higher incidence of previous MI (33.1% vs 12.6%). They were less likely to present with anterior STEMI (15.7% vs 33.9%) and less likely to be revascularized or to receive mechanical circulatory support. Patients with STEMI and previous CABG had a slightly higher incidence of in-hospital death (8.8% vs 8.1%, relative difference 7.9%), stroke (3.9% vs 2.8%), and 30-day urgent readmission (7% vs 5.3%). Approximately 67.6% were revascularized (95.6% with PCI, 6.4% with CABG, and 2% with both). There was a significant downward trend in revascularization of STEMI patients during the study period (71.9% in the first quarter of 2016 to 63.7% in the last quarter of 2019, p-trend <0.001).

Only 46.4% of patients with previous CABG were revascularized (93% with PCI, 10.3% with redo CABG, and 3.3% with both), whereas 68.8% of patients without previous CABG were revascularized (95.7% with PCI, 6.2% with CABG, and 2% with both). There was a significant downward trend in revascularization of both groups during the study period, without a change in the trends for revascularization methods (previous CABG, from 55.2% to 44.6%, p <0.001; no previous CABG, 73.1% to 64.8%, p <0.001) (Supplementary Figure 1).

During the study period, a total of 1,545,063 patients presented with NSTEMI (accounting for a national estimate of 2,821,050 patients). Of those, 12.3% had a history of CABG. Differences in baseline characteristics and outcomes between patients with NSTEMI who had previous CABG and those who did not are listed in Table 3. Among patients who presented with NSTEMI, patients with previous CABG were older (age 74 vs 70 years), less likely to be women (29.7% vs 44.0%), had more comorbidities, had a higher incidence of previous MI (30.1% vs 14.6%). Patients with previous CABG who presented with NSTEMI had a slightly lower incidence of in-hospital mortality (6.8% vs 8%, relative difference 15%) and stroke (2.2% vs 2.9%, p <0.001) than those without previous CABG.

Table 1
Baseline characteristics and outcomes of previous CABG patients presenting with myocardial infarction

Variable	STEMI (n = 24,264)	NSTEMI (n = 189,601)
Age, median (IQR) (years)	71 (62-79)	74 (66-82)
Women	24.8%	29.7%
Morbid obesity	4.6%	6%
Hypertensio	88.7%	92.2%
Diabetes mellitus	45.4%	57.4%
Coagulopathy	9.2%	9.3%
Chronic pulmonary disease	23.3%	27.8%
Atrial fibrillation/flutter	33.9%	32.5%
Congestive heart failure	50.3%	57.8%
Cartotid artery disease	3.3%	4.2%
Prior MI	33.1%	30.1%
Prior stroke	12.3%	13.4%
History of ICD	9.6%	7%
History of PPM	5.1%	7.7%
Severe renal disease	7.8%	15%
Severe liver disease	0.6%	0.7%
Hospital and payer		
Large sized hospital	61.2%	56.5%
Teaching hospital	72.3%	68.2%
Medicare	71.3%	79.6%
Presentation		
Anterior wall STEMI (%)	15.7%	NA
Mechanical circulatory support		
Impella	1.6%	0.7%
ECMO	0.4%	0.1%
Intra-aortic balloon pump	5.8%	1.5%
Treatment		
PCI	43.1%	26.8%
CABG	4.8%	3.9%
PCI and CABG	1.5%	0.2%
Outcomes		
In-hospital mortality	8.8%	6.8%
Discharge to a facility	13.7%	18.6%
LOS, (median, IQR) (days)	3 (2-7)	4 (2-7)
Cost, (median, IQR) (dollars)	18,019 (10,549-30,010)	14,633 (8,161-25,197)
Urgent readmission within 30-days (%)	7%	4.3%
Cardiogenic shock (%)	10.8%	4.2%
Ventricular tachycardia	11.1%	6.3%
Stroke	3.9%	2.2%
Ischemic stroke	3.3%	1.8%
Hemorrhagic stroke	0.9%	0.5%
Mixed (ischemic and hemorrhagic strokes)	0.3%	0.1%
Major amputation	0.2%	0.25%
Minor amputation	0.2%	0.3%
Major bleeding	11.7%	12.4%
Blood transfusion	4.8%	6.5%
AKI leading to hemodialysis	1.4%	1.8%

IQR = interquartile range; ICD = implantable cardioverter-defibrillator; PCI = percutaneous coronary intervention; CABG = coronary artery bypass surgery; STEMI = ST-segment elevation myocardial infarction; PPM = permanent pacemaker, ECMO = extracorporeal membrane oxygenation.

Table 2
Baseline characteristics and outcomes of admissions presenting with STEMI

Variable	History of CABG (n = 24,264)	No history of CABG (n = 425,171)
Age, median (IQR) (years)	71 (62-79)	64 (55-73)
Women	24.8%	32.6%
Morbid obesity	4.6%	5.3%
Hypertension	88.7%	73.2%
Diabetes mellitus	45.4%	31.5%
Anemia	18.4%	12.3%
Coagulopathy	9.2%	7.4%
Chronic pulmonary disease	23.3%	17%
Atrial fibrillation/flutter	33.9%	21%
Congestive heart failure	50.3%	33.5%
Carotid artery disease	3.3%	1.3%
Prior MI	33.1%	12.6%
Prior stroke	12.3%	6.3%
History of ICD	9.6%	2.2%
History of PPM	5.1%	1.5%
Severe renal disease	7.8%	4.1%
Severe liver disease	0.6%	0.7%
Hospital and payer		
Large sized hospital	61.2%	60.7%
Teaching hospital	72.3%	73.1%
Medicare	71.3%	48.4%
Presentation		
Anterior wall STEMI	15.7%	33.9%
Mechanical circulatory support		
Impella	1.6%	2.2%
ECMO	0.4%	0.5%
Intra-aortic balloon pump	5.8%	6.4%
Treatment		
PCI	43.9%	65.8%
CABG	4.8%	4.3%
PCI and CABG	1.5%	1.4%
Outcomes		
In-hospital mortality,	8.8%	8.1%
Discharge to a facility	13.7%	10.8%
LOS, (median, IQR) (days)	3 (2-7)	3 (2-6)
Cost, (median, IQR) (dollars)	18,019 (10,549-30,010)	20,212 (13,935-31,553)
Urgent readmission within 30-days	7%	5.3%
Cardiogenic shock	10.8%	12.4%
Ventricular tachycardia	11.1%	12.1%
Stroke	3.9%	2.8%
Ischemic stroke	3.3%	2.3%
Hemorrhagic stroke	0.9%	0.8%
Mixed (ischemic and hemorrhagic strokes)	0.3%	0.2%
Major amputation	0.2%	0.1%
Major bleeding	11.7%	9.3%
Blood transfusion	4.8%	3.7%
AKI leading to hemodialysis	1.4%	1.4%

IQR = interquartile range; ICD = implantable cardioverter-defibrillator; PCI = percutaneous coronary intervention; CABG = coronary artery bypass surgery; STEMI = ST-segment elevation myocardial infarction; PPM = permanent pacemaker, ECMO = extracorporeal membrane oxygenation.

Approximately 36% were revascularized (78.4% with PCI, 22.4% with CABG, and 0.8% with both). There was a significant upward trend in revascularization of patients with NSTEMI during the study period (32.3% in the first quarter of 2016 to 40.1% in the last quarter of 2019, p <0.001). Approximately 30.6% of patients with previous CABG who presented with NSTEMI were revascularized (87.8% with PCI, 13.0% with redo CABG, and 0.7% with both), whereas 36.7% of patients without previous CABG were revascularized (77.3% with PCI, 23.5% with CABG, and 0.8% with both). There was a significant upward trend in revascularization of both groups during the study period, without a change in the trends of revascularization methods (previous CABG, 27.3% to 34.4%, p <0.001; no previous CABG, 33.1% to 40.9%, p <0.001) (Supplementary Figure 2).

After adjustment for baseline characteristics, comorbidities, and presentation, previous CABG was associated with a slightly lower risk of in-hospital mortality in patients who presented with NSTEMI (OR 0.85, 95% CI 0.82 to 0.86, p <0.001) (Supplementary Table 2). However, previous CABG was associated with a slightly higher risk of in-hospital mortality in patients who presented with STEMI (OR 1.06, 95% CI 1.01 to 1.13, p = 0.023) (Supplementary Table 3).

In patients with MI and previous CABG, after adjustment for multiple variables revascularization was associated with a lower risk of in-hospital mortality in both patients who presented with STEMI (OR 0.30, 95% CI 0.26 to 0.35, p <0.001) and patients who presented with NSTEMI (OR 0.21, 95% CI 0.19 to 0.23, p <0.001) (Supplementary Tables 4 and 5).

A summary of the study results is presented in Figure 4.

Discussion

The main findings of the study can be summarized as follows: (1) among patients who presented with MI in the US from 2016 to 2019, 10.3% had previous CABG (with a 10% downward trend during the study period), (2) patients with previous CABG were less likely to present with STEMI than were patients without previous CABG (11.8% vs 24.3%) (with a 44% increase in presentation with STEMI during the study period), (3) patients with MI and previous CABG were less likely to be revascularized than were those without previous CABG (32.5% vs 44.4%), even when they presented with STEMI (46.4% vs 68.4%), (4) previous

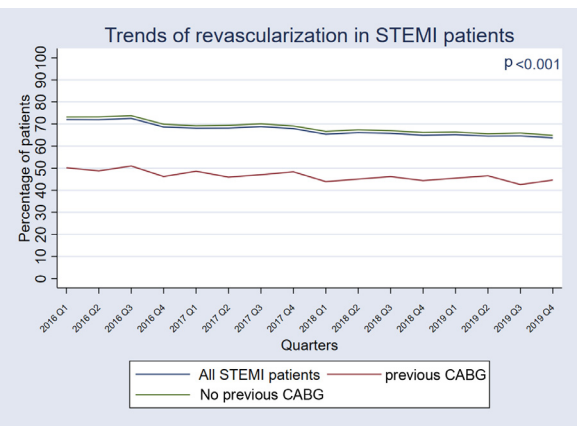

Figure 4. Summary of the study results. Q = quarter.

Table 3
Baseline characteristics and outcomes of admissions presenting with NSTEMI

Variable	History of CABG	
	Yes (n = 189,601)	No (n = 1,355,462)
Age, median (IQR) (years)	74 (66-88)	70 (60-80)
Women	29.7%	44%
Morbid obesity	6%	7.4%
Hypertension	92.2%	83%
Diabetes mellitus	57.4%	42.2%
Coagulopathy	9.3%	10.1%
Chronic pulmonary disease	27.8%	26.6%
Atrial fibrillation/flutter	32.5%	25.7%
Congestive heart failure	57.8%	44.8%
Carotid artery disease	4.2%	2.7%
Prior MI	30.1%	14.6%
Prior stroke	13.4%	8.7%
History of ICD	7%	2%
History of PPM	7.7%	3.3%
Severe renal disease	15%	11.1%
Severe liver disease	0.7%	1.1%
Hospital and payer		
Large sized hospital	56.5%	56.5%
Teaching hospital	68.2%	69.5%
Medicare	80%	65.7%
Mechanical circulatory support		
Impella	0.7%	0.8%
ECMO	0.08%	0.11%
Intra-aortic balloon pump	1.5%	2%
Treatment		
PCI	26.8%	28.3%
CABG	3.9%	8.6%
PCI and CABG	0.2%	0.3%
Outcomes		
In-hospital mortality	6.8%	8%
Discharge to a facility	18.6%	21.4%
LOS, (median, IQR) (days)	4 (2-7)	4 (2-8)
Cost, (median, IQR) (dollars)	14,633 (8,161-25,197)	16,777 (94,60- 30,149)
Urgent readmission within 30-days	4.3%	4.1%
Cardiogenic shock	4.2%	4.6%
Ventricular tachycardia	6.3%	5.4%
Stroke	2.2%	2.9%
Ischemic stroke	1.8%	2.3%
Hemorrhagic stroke	0.5%	0.8%
Mixed (ischemic and hemorrhagic strokes)	0.1%	0.2%
Major amputation	0.25%	0.22%
Minor amputation	0.3%	0.2%
Major bleeding	12.4%	12.5%
Blood transfusion	6.5%	6.6%
AKI leading to hemodialysis	1.8%	2.2%

IQR = interquartile range; ICD = implantable cardioverter-defibrillator; PCI = percutaneous coronary intervention; CABG = coronary artery bypass surgery; STEMI = ST-segment elevation myocardial infarction; PPM = permanent pacemaker, ECMO = extracorporeal membrane oxygenation.

CABG was associated with a lower risk of in-hospital mortality in patients who presented with NSTEMI and with a higher risk of in-hospital death in patients who presented with STEMI, and (5) revascularization (with PCI or redo CABG) during admission was associated with higher survival rate in patients with previous CABG who presented with STEMI or NSTEMI.

In the US, approximately 1 in 10 patients who presented with MI had previous CABG. Most of these patients presented with NSTEMI; only a minority presented with STEMI. Given the demographics and characteristics of these patients (older age and greater comorbidity burden), they were at higher risk of NSTEMI presentation.[16] Moreover, SVG failure more often leads to nonocclusive disease,[17,18] and patients with previous CABG were likely treated with guideline-directed medical therapy, including secondary prevention with aspirin, that may reduce the risk of an acute thrombotic occlusion in favor of a more insidious NSTEMI presentation. Given the excellent patency of IMA grafts,[10] these patients were less likely to present with anterior MI. If patent, grafts can bypass the acute thrombotic occlusions in proximal vessels, lowering the likelihood of STEMI presentation.

In our analysis, NSTEMI patients with previous CABG had a slightly lower overall in-hospital mortality than those without previous CABG; this finding was confirmed on multivariate regression analysis. The protective effect of CABG in patients with NSTEMI can be explained by the factors mentioned above (previous protective medical therapy, protection against anterior STEMI by the superior patency of the left IMA graft, bypass, and so forth). However, patients with previous CABG who presented with STEMI had a higher risk of death than those without previous CABG after adjusting for age and comorbidities, despite their much lower likelihood of presenting with anterior STEMI (15.7% vs 33.9%). Half of patients with previous CABG have unrevascularized chronic total occlusions (CTOs).[19] The occurrence of STEMI in patients with previous CABG can be associated with a higher risk of "double jeopardy," because an occluded vessel might have been supplying unrevascularized CTO territory through collateral vessels, extending the territory at risk.

In our analysis, revascularization was associated with significantly lower risk of in-hospital death in patients with STEMI and NSTEMI after adjusting for age and comorbidities; this finding is concordant with previous studies.[20] This subset of patients carries a higher risk and requires more aggressive treatment than patients who are CABG-naive. However, revascularization is less often performed in these patients, as shown in previous studies, including patients with STEMI and NSTEMI presentations.[20,21] In our analysis, patients with previous CABG were less likely to be revascularized even when they presented with STEMI. The higher disease complexity in these patients may explain this finding. CABG accelerates atherosclerosis and CAD in native vessels, leading to more complex disease and CTOs.[5] Without appropriate expertise to treat complex native CAD, interventional cardiologists likely default their treatment to medical therapy.

Our analysis showed a significant downward trend in revascularization of patients presenting with STEMI, including those with previous CABG. A previous study using the nationwide inpatient sample has shown that in-hospital PCI was performed more frequently for STEMI than for other indications recently (14% from 2013 to 2016 vs 7.2% from 2003 to 2007). However, the absolute

number of patients treated for STEMI decreased during those years (262,858 vs 281,148 patients for the same periods). The same trend was noted in CABG for patients with MI in the same study.[22] Our provocative findings should be further validated using large clinical databases, such as the National Cardiovascular Data Registry's Chest Pain-MI Registry. Unlike the trend noted in patients with STEMI, there was an upward trend in revascularization of patients with NSTEMI, including those with previous CABG. In 2016, Tegn et al[23] showed the superiority of the invasive strategy in older populations, which may also partially explain the uptake of revascularization. Revascularization of patients with NSTEMI who have complex anatomy may also be delayed to allow a second opinion from a more experienced operator, eventually leading to revascularization in a more stable environment with the appropriate expertise. This situation is unlike STEMI or cardiogenic shock, where immediate action is needed or, if not, the decision is either medical therapy or palliative care. Moreover, SVG disease is more likely to present with NSTEMI than STEMI, except in very early failure.[17,18] Although less preferred than native disease treatment, focal SVG PCI is easier to perform and more likely to be tackled than the complex native CAD.

Our findings of better survival with revascularization should be interpreted carefully, given the observational nature of our study, the inherent limitations of selection bias, and the lack of data for important variables (such as ejection fraction, anatomical details, and so on). The findings are also limited by the indication bias; it is expected that some patients who were not revascularized had more complex disease than those who could be revascularized. Nevertheless, the data suggest that we should strive to achieve early revascularization in these patients, despite their complex anatomy, whenever possible.

Disclosures

The authors disclose the following relations: Dr. Khaldoon Alaswad: consulting/speaker honoraria from Boston Scientific, Cardiovascular Systems, Abbott Vascular, Teleflex; Dr. Mir Basir: consulting/speaker Abbott Vascular, Abiomed, Cardiovascular Systems, Chiesi, ZOLL. Dr. Emmanouil Brilakis: consulting/speaker honoraria from Abbott Vascular, American Heart Association (Associate Editor, *Circulation*), Amgen, Asahi Intecc, BIOTRONIK, Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), ControlRad, CSI, Elsevier, GE Healthcare (Little Chalfont, United Kingdom), IMDS, Infraredx, Medicure, Medtronic, Opsens, Siemens, Teleflex; research support from Boston Scientific, GE Healthcare; owner, Hippocrates LLC; shareholder, MHI Ventures, Cleerly, Stallion Medical. Dr. Stephane Rinfret: consultant Boston Scientific, Abiomed, Abbott Vascular, and Soundbite Medical. Dr. Santiago Garcia: consultant for Surmodics, Osprey Medical, Medtronic, Edwards Lifesciences, Abbott; grant support from Edwards Lifesciences and the US Department of Veterans Affairs' Office of Research and Development. The remaining authors have no conflicts of interests to declare.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2022.06.002.

1. Serruys PW, Morice MC, Kappetein AP, Colombo A, Holmes DR, Mack MJ, Ståhle E, Feldman TE, van den Brand M, Bass EJ, Van Dyck N, Leadley K, Dawkins KD, Mohr FW. SYNTAX Investigators. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. *N Engl J Med* 2009;360:961–972.
2. Farkouh ME, Domanski M, Sleeper LA, Siami FS, Dangas G, Mack M, Yang M, Cohen DJ, Rosenberg Y, Solomon SD, Desai AS, Gersh BJ, Magnuson EA, Lansky A, Boineau R, Weinberger J, Ramanathan K, Sousa JE, Rankin J, Bhargava B, Buse J, Hueb W, Smith CR, Muratov V, Bansilal S, King S III, Bertrand M, Fuster V. FREEDOM Trial Investigators. Strategies for multivessel revascularization in patients with diabetes. *N Engl J Med* 2012;367:2375–2384.
3. Sabatine MS, Bergmark BA, Murphy SA, O'Gara PT, Smith PK, Serruys PW, Kappetein AP, Park SJ, Park DW, Christiansen EH, Holm NR, Neilsen PH, Stone GW, Sabik JF, Braunwald E. Percutaneous coronary intervention with drug-eluting stents versus coronary artery bypass grafting in left main coronary artery disease: an individual patient data meta-analysis [published correction appears in *Lancet* 2022;399:1606]. *Lancet* 2021;398:2247–2257.
4. Park SJ, Ahn JM, Kim YH, Park DW, Yun SC, Lee JY, Kang SJ, Lee SW, Lee CW, Park SW, Choo SJ, Chung CH, Lee JW, Cohen DJ, Yeung AC, Hur SH, Seung KB, Ahn TH, Kwon HM, Lim DS, Rha SW, Jeong MH, Lee BK, Tresukosol D, Fu GS, Ong TK. BEST Trial Investigators. Trial of everolimus-eluting stents or bypass surgery for coronary disease. *N Engl J Med* 2015;372:1204–1212.
5. Pereg D, Fefer P, Samuel M, Wolff R, Czarnecki A, Deb S, Sparkes JD, Fremes SE, Strauss BH. Native coronary artery patency after coronary artery bypass surgery. *JACC Cardiovasc Interv* 2014;7:761–767.
6. Lamy A, Eikelboom J, Sheth T, Connolly S, Bosch J, Fox KAA, Zhu J, Lonn E, Dagenais G, Widimsky P, Branch KRH, Bhatt DL, Zheng Z, Straka Z, Dagenais F, Kong Y, Marsden T, Lee SF, Copland I, Yusuf S. Rivaroxaban, aspirin, or both to prevent early coronary bypass graft occlusion: the COMPASS-CABG study. *J Am Coll Cardiol* 2019;73:121–130.
7. Henderson RA, Pocock SJ, Sharp SJ, Nanchahal K, Sculpher MJ, Buxton MJ, Hampton JR. Long-term results of RITA-1 trial: clinical and cost comparisons of coronary angioplasty and coronary-artery bypass grafting. *Lancet* 1998;352:1419–1425.
8. Risum O, Abdelnoor M, Svennevig JL, Levorstad K, Nitter-Hauge S. Risk factors of recurrent angina pectoris and of non-fatal myocardial infarction after coronary artery bypass surgery. *Eur J Cardiothorac Surg* 1996;10:173–178.
9. Campbell PG, Teo KSL, Worthley SG, Kearney MT, Tarique A, Natarajan A, Zaman AG. Non-invasive assessment of saphenous vein graft patency in asymptomatic patients. *Br J Radiol* 2009;82:291–295.
10. Goldman S, Zadina K, Moritz T, Ovitt T, Sethi G, Copeland JG, Thottapurathu L, Krasnicka B, Ellis N, Anderson RJ, Henderson W. VA Cooperative Study Group #207/297/364. Long-term patency of saphenous vein and left internal mammary artery grafts after coronary artery bypass surgery: results from a Department of Veterans Affairs Cooperative Study. *J Am Coll Cardiol* 2004;44:2149–2156.
11. Khorsandi M, Dougherty S, Bouamra O, Pai V, Curry P, Tsui S, Clark S, Westaby S, Al-Attar N, Zamvar V. Extra-corporeal membrane oxygenation for refractory cardiogenic shock after adult cardiac surgery: a systematic review and meta-analysis. *J Cardiothorac Surg* 2017;12:55.
12. Elbadawi A, Elzeneini M, Elgendy IY, Megaly M, Omer M, Jimenez E, Ghanta RK, Brilakis ES, Jneid H. Coronary artery bypass grafting after acute ST-elevation myocardial infarction [published online March 31,.2021]. *J Thorac Cardiovasc Surg* 2021. https://doi.org/10.1016/j.jtcvs.2021.03.081.
13. Elbadawi A, Hamed M, Elgendy IY, Omer MA, Ogunbayo GO, Megaly M, Denktas A, Ghanta R, Jimenez E, Brilakis E, Jneid H. Outcomes of reoperative coronary artery bypass graft surgery in the United States. *J Am Heart Assoc* 2020;9:e016282.

14. Khera R, Angraal S, Couch T, Welsh JW, Nallamothu BK, Girotra S, Chan PS, Krumholz HM. Adherence to methodological standards in research using the National Inpatient Sample. *JAMA* 2017;318:2011–2018.
15. Houchens R, Ross D, Elixhauser A. *Using the HCUP National Inpatient Sample to estimate trends*. HCUP methods series report # 2006-05. U.S. Agency for Healthcare Research and Quality; 2015. Available at https://www.hcup-us.ahrq.gov/reports/methods/2006_05_NISTrendsReport_1988-2004A.pdf.
16. Kytö V, Sipilä J, Rautava P. Association of age and gender with risk for non-ST-elevation myocardial infarction. *Eur J Prev Cardiol* 2015;22:1003–1008.
17. Redfors B, Généreux P, Witzenbichler B, McAndrew T, Diamond J, Huang X, Maehara A, Weisz G, Mehran R, Kirtane AJ, Stone GW. Percutaneous coronary intervention of saphenous vein graft. *Circ Cardiovasc Interv* 2017;10:e004953.
18. Xenogiannis I, Zenati M, Bhatt DL, Rao SV, Rodés-Cabau J, Goldman S, Shunk KA, Mavromatis K, Banerjee S, Alaswad K, Nikolakopoulos I, Vemmou E, Karacsonyi J, Alexopoulos D, Burke MN, Bapat VN, Brilakis ES. Saphenous vein graft failure: from pathophysiology to prevention and treatment strategies. *Circulation* 2021;144:728–745.
19. Fefer P, Knudtson ML, Cheema AN, Galbraith PD, Osherov AB, Yalonetsky S, Gannot S, Samuel M, Weisbrod M, Bierstone D, Sparkes JD, Wright GA, Strauss BH. Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. *J Am Coll Cardiol* 2012;59:991–997.
20. Shoaib A, Rashid M, Berry C, Curzen N, Kontopantelis E, Timmis A, Ahmad A, Kinnaird T, Mamas MA. Clinical characteristics, management strategies, and outcomes of non−ST-segment−elevation myocardial infarction patients with and without prior coronary artery bypass grafting. *J Am Heart Assoc* 2021;10:e018823.
21. Welsh RC, Granger CB, Westerhout CM, Blankenship JC, Holmes DR Jr, O'Neill WW, Hamm CW, Van de Werf F, Armstrong PW. APEX AMI Investigators. Prior coronary artery bypass graft patients with ST-segment elevation myocardial infarction treated with primary percutaneous coronary intervention. *JACC Cardiovasc Intv* 2010;3:343–351.
22. Alkhouli M, Alqahtani F, Kalra A, Gafoor S, Alhajji M, Alreshidan M, Holmes DR, Lerman A. Trends in characteristics and outcomes of hospital inpatients undergoing coronary revascularization in the United States, 2003−2016. *JAMA Netw Open* 2020;3:e1921326.
23. Tegn N, Abdelnoor M, Aaberge L, Endresen K, Smith P, Aakhus S, Gjertsen E, Dahl-Hofseth O, Ranhoff AH, Gullestad L, Bendz B. After Eighty study investigators. Invasive versus conservative strategy in patients aged 80 years or older with non-ST-elevation myocardial infarction or unstable angina pectoris (After Eighty study): an open-label randomised controlled trial. *Lancet* 2016;387:1057–1065.