Nationwide Trends and Outcomes for Coronary Artery Bypass Grafting in End-Stage Kidney Disease and Stable Coronary Artery Disease

Rhythm Vasudeva, MD[a], Harsh Mehta, MD[a], Wan-Chi Chan, MD[a], Monil Majmundar, MD[a], Sri G. Yarlagadda, MD[b], Peter Downey, MD[c], Emmanuel Daon, MD[c], Greg Muehlebach, MD[c], Matthew Danter, MD[c], George Zorn, MD[c], Mark Wiley, MD[a], Peter Tadros, MD[a], Eric Hockstad, MD[a], and Kamal Gupta, MD[a,*]

Patients with end-stage kidney disease (ESKD) on dialysis have an increased burden of coronary artery disease (CAD). This study assessed the trend and outcomes for coronary artery bypass surgery (CABG) in patients with ESKD and stable CAD. We conducted a longitudinal study using the United States Renal Data System of patients with ESKD and stable CAD who underwent CABG from the years 2009 to 2017. The outcomes included in-hospital, long-term mortality, and repeat revascularization. The follow-up was until death, end of Medicare AB coverage, or December 31, 2018. A total of 11,952 patients were identified. The mean age was 62.8 years, 68% were male, and 67% were white. The common comorbidities included hypertension (97%), diabetes mellitus (75%), and congestive heart failure (53%). A significant decrease in CABG procedures from 2.9 to 1.3 procedures per 1,000 patients with ESKD (p <0.001) was noted during the years studied. The overall in-hospital mortality rate was 5.9%, and there was a significant decrease over the study period (p = 0.01). Although the 30-day mortality rate was 6.9% and remained steady (p = 0.14), the 1-year mortality rate was 22.8% and decreased significantly (p <0.001). At 5 years, the overall survival rate was 35%, and patients with internal mammary artery grafts showed better survival than those without (36% vs 25%). In conclusion, there has been a decrease in CABG procedures performed in patients with ESKD with stable CAD with decreasing in-hospital and 1-year mortality. Those with an internal mammary artery graft do better, but the overall long-term survival remains dismal in this population. There remains need for caution and individualization of revascularization decisions in this high-risk population. **(Am J Cardiol 2024;210:37−43)**

Keywords: ESKD, dialysis, CAD, CABG

Patients with end-stage kidney disease (ESKD) who are on dialysis carry an increased burden of cardiovascular diseases, particularly, coronary artery disease (CAD), which is the leading cause of mortality in this population.[1,2] CAD in ESKD is characterized by diffusely diseased vessels, with multivessel involvement, heavy plaque burden and calcification, and characteristics that make any revascularization more challenging.[3,4] Coronary artery bypass surgery (CABG), which is usually a good revascularization strategy for multivessel calcified coronary arteries, has been associated with several-fold higher per-procedural mortality in patients with ESKD than the general population.[5,6]

For stable CAD in patients with ESKD, data are lacking regarding CABG and outcomes compared with medical therapy. A recent randomized controlled trial (RCT) that compared an early invasive strategy to medical therapy in patients with advanced kidney disease with stable CAD found no benefit of the invasive therapy.[7] However, this was not a comparison of CABG with medical therapy because only about 15% of those revascularized underwent CABG. Thus, at the present time, there is significant controversy without clear evidence regarding the role of CABG in this patient population. The most recent nationwide data available (2004 to 2009) indicates that 46% of all coronary revascularizations occur for nonacute coronary syndrome indications in the ESKD population on dialysis.[8] There are no contemporary data available on the subject. We conducted this analysis of the United States Renal Data System (USRDS) from years 2010 to 2017 to study the trends in CABG use and outcomes, such as periprocedural and long-term mortality, in patients with ESKD with stable CAD who were on chronic dialysis.

Methods

For this analysis, we conducted a longitudinal study using the USRDS from 2010 to 2017. The USRDS provides

[a]Department of Cardiovascular Medicine, University of Kansas Medical Center, Kansas City, Kansas; [b]Division of Nephrology and Hypertension, Department of Internal Medicine, University of Kansas Medical Center, Kansas City, Kansas; and [c]Department of Cardiovascular and Thoracic Surgery, University of Kansas Medical Center, Kansas City, Kansas.
Manuscript received August 1, 2023; revised manuscript received and accepted October 2, 2023.

Funding: none.

See page 42 for Declaration of Competing Interest.

*Corresponding author: Tel: 913-588-9600.

E-mail address: kgupta@kumc.edu (K. Gupta).

0002-9149/© 2023 Elsevier Inc. All rights reserved.
https://doi.org/10.1016/j.amjcard.2023.10.004

comprehensive administrative records for almost 95% of patients with ESKD in the United States.[1] We included patients aged 18 years or older, with ESKD on dialysis for at least 3 months, who underwent CABG for stable CAD. Thus, we excluded patients who had any myocardial infarction−related hospitalization. We further excluded patients with CABG and concomitant valve surgery, CABG with percutaneous coronary intervention during the same hospitalization, and renal transplant before or during hospitalization for CABG. We also excluded patients who did not have combined Medicare Part A and Part B coverage during the index hospitalization as the primary payer. This was done to ensure that we had a continuous co-morbidity and outcomes assessment for the study period. The relevant International Classification of Diseases, Ninth and Tenth Revision diagnostic and procedure codes and the Center for Medicare and Medicaid Services Form 2728 were used to identify the specific conditions and procedures. (Supplementary Table 1). The use of the internal mammary artery (IMA) conduit was also identified using appropriate International Classification of Diseases, Ninth and Tenth Revision diagnostic and procedure codes.

The primary outcome of interest was death from any cause. The follow-up for the primary outcomes was until death, end of Medicare AB coverage, or study end-date of December 31, 2018, whichever was earlier. Other outcomes assessed were in-hospital mortality (death during index hospitalization for CABG), 30-day mortality (death during index hospitalization and up to 30 days after CABG), and 1-year and 5-year mortality (death during index hospitalization and up to 1 year and 5 years after CABG, respectively). We also studied the 1-year incidence of repeat revascularization (surgical or percutaneous) after discharge after CABG. We estimated the long-term survival using the Kaplan−Meier method. The trend analysis was performed using Cochran−Armitage test. All reported p values are 2-sided. Statistical analyses were performed using the SAS 9.4 (SAS Institute Inc, Cary, North Carolina) software.

Results

A total of 11,952 patients with ESKD with stable CAD were identified as having undergone CABG over the years 2010 to 2017. Figure 1 shows the details of the subjects enrolled and the study inclusions and exclusions. Table 1 lists the demographic and baseline characteristics categorized into those having received an IMA graft or not having received an IMA graft. For the overall group, the mean age was 62.8 years, 68% were male, and a majority were white (67%). Most patients (85%) had been on dialysis for 5 years or less, with hemodialysis being the principal modality of dialysis (88%). The most common co-morbidities included hypertension (97%), diabetes mellitus (75%), congestive heart failure (53%), and peripheral vascular disease (28%). A majority of patients (80%) received IMA graft. Patients with an IMA graft had greater prevalence of diabetes and peripheral vascular disease but had a lower overall co-morbidity burden. The overall occurrence of critical limb ischemia was 4% and was comparable to patients who received IMA versus those who did not.

Figure 2 demonstrates the CABG trends over the years studied. Over the period studied, there was a significant decrease in the number of CABG procedures performed for stable CAD (2.9 CABG procedures per 1,000 patients with ESKD in 2010 to 1.3 CABG procedures per 1,000 patients with ESKD in 2017). During the same period, the number of patients receiving IMA graft also decreased from 2.2 CABG procedures with IMA per 1,000 patients with ESKD in 2010 to 1.1 CABG procedures with IMA per 1,000 patients with ESKD in 2017. A similar downward trend was noted for CABG procedures without IMA in this population (0.6 to 0.2 CABG procedures without IMA per 1,000 patients with ESKD over the study period).

Table 2 lists the study outcomes for in-hospital, 30-day, and 1-year mortality rates over the study period and the 1-year repeat revascularization rates. The overall in-hospital mortality rate was 5.9%. There was a significant decrease in the in-hospital mortality during the study period (6.4% in 2010 to 4.7% in 2017). The 30-day mortality rate was 6.9% for the overall CABG group and this did not change significantly over the study duration. The 1-year mortality was high at 22.8%, with a consistent and significant decrease from 2010 to 2017 (24.5% to 18.5%). Similarly, the 5-year mortality rate showed a decreasing trend from 67.2% in 2010 to 65.1% in 2013; however, this was not statistically significant ($p = 0.195$). The overall trends for these outcomes and their comparison in the subgroups of patients who received an IMA graft versus those who did not are listed in Supplementary Table 2.

Figure 3 shows the survival curves for patients who underwent CABG and compares those who received IMA graft and those who did not. Patients who received an IMA graft had a significantly lower in-hospital mortality than those without (4.9% vs 10.1%, $p < 0.0001$). Patients with IMA also had significantly lower 30-day (6.0% vs 10.1%, $p < 0.0001$), 1-year (20.7% vs 30.7%), and 5-year mortality rates (63.9% vs 74.7%). Additional sensitivity analyses revealed that the short- and long-term mortality after CABG was directly proportional to the duration on dialysis before procedure (Supplementary Table 3).

Acute myocardial infarction (AMI) occurred in 8.4% of patients within 1 year of having undergone CABG and in 29.5% within 5 years. The rates of AMI (8.2% vs 9.1%) and repeat revascularization (4.3% vs 4.6%) at 1 year were slightly lower in patients who received an IMA versus those who did not but were not statistically significant. There was no significant change in the rate of repeat revascularization within 1 year over the study period ($p = 0.75$) (Table 2).

Discussion

This large, nationwide study attempts to bridge the knowledge gaps and provide contemporary data for trends and outcomes of surgical coronary revascularization in patients with ESKD and stable CAD. The main findings of this study are that there has been a consistent and significant decrease in the number of CABG procedures performed over the past decade, there was a significant decrease in short- and long-term mortality from 2010 to 2017 (although longer terms outcomes remain poor), and that those receiving an IMA graft have a significant survival advantage.

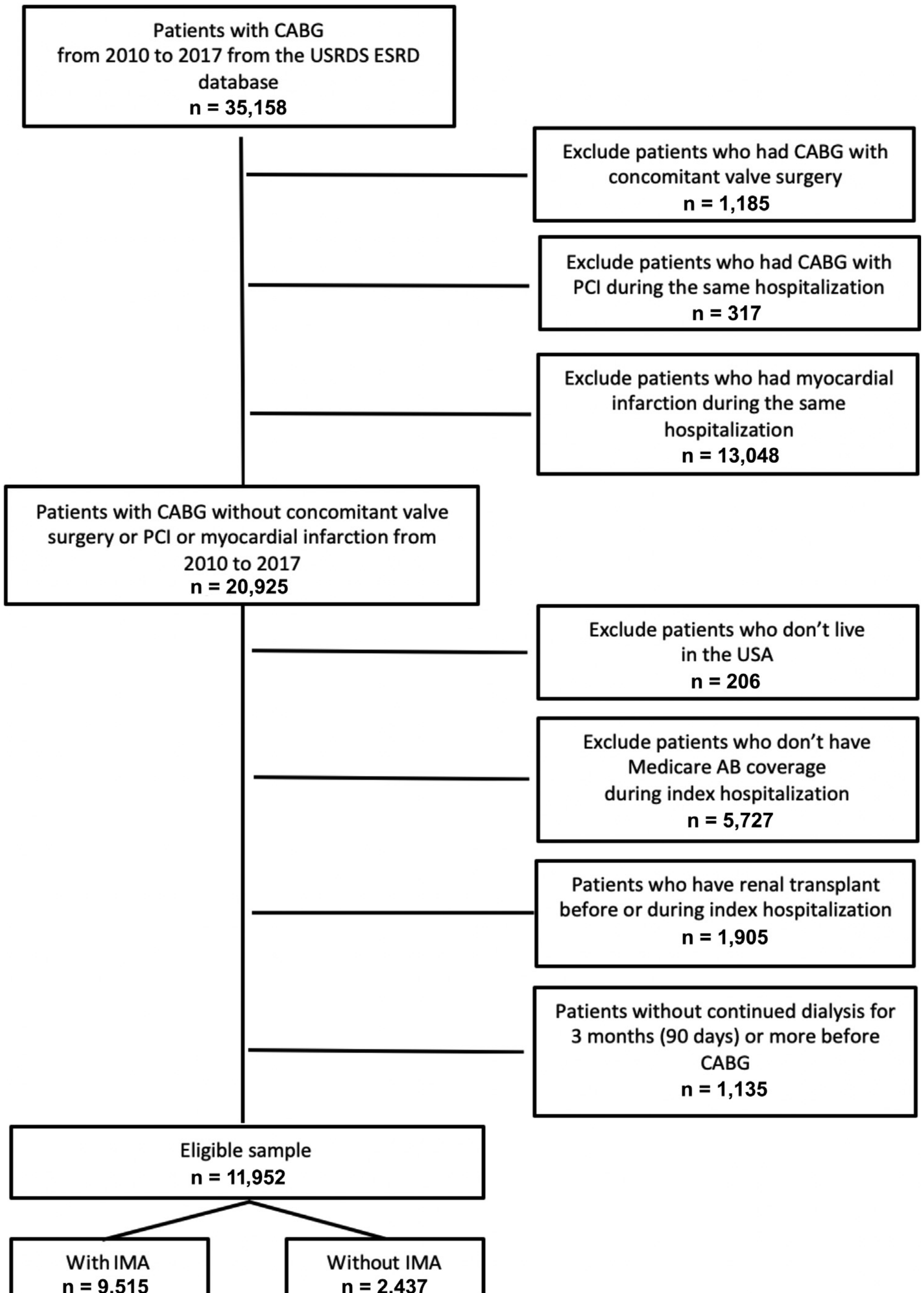

Figure 1. Consort diagram showing derivation of study population. PCI = percutaneous coronary intervention.

Patients with ESKD have significant premature CAD and often have adverse coronary anatomy, including multivessel and diffuse CAD with significant arterial calcification.[3,4,9] Thus, they are at a high risk for atherosclerotic cardiovascular events.[1,9] However, their high cardiovascular mortality is not from CAD alone because a myriad of other factors, such as myocardial hypertrophy and fibrosis and risk of sudden death from ischemia and hypotension during hemodialysis, also play a role.[10] Thus, revascularization procedures can only have a limited impact on outcomes such as mortality. To have a meaningful impact on outcomes, any coronary revascularization procedure, such as CABG, should have a low perioperative mortality.

In the general (non-ESKD) population, there is a large body of evidence based on several well-conducted RCTs that informs that most patients (even those with significant ischemia on noninvasive testing and those with significant coronary stenosis) do well with medical therapy compared with revascularization.[11,12] However, these studies mostly excluded patients with ESKD or had a very small

Table 1
Baseline demographic characteristics and comorbid conditions of ESKD patients undergoing CABG for stable CAD

Characteristic	CABG total (n= 11952)	With IMA (n= 9515)	Without IMA (n-2437)	P-value
N (%)	100%	80%	20%	
Male sex, n (%)	8123 (68%)	6591 (69%)	1532 (63%)	<0.0001
Race, n (%)				0.0019
White	7973 (67%)	6351 (67%)	1622 (67%)	
Black	3120 (26%)	2444 (26%)	676 (27%)	
Other / unknown	859 (7%)	720 (8%)	139 (6%)	
Mean Age (years), (SD)	62.8 (10.5)	62.5 (10.5)	64.1 (10.8)	<0.0001
Age groups, n (%)				<0.0001
<50	1376 (12%)	1132 (12%)	244 (10%)	
50-64	5271 (44%)	4287 (45%)	984 (40%)	
65-79	4830 (40%)	3767 (40%)	1063 (44%)	
≥80	475 (4%)	329 (4%)	146 (6%)	
Dialysis duration (years), n (%)				<0.0001
<2	5013 (42%)	4175 (44%)	838 (34%)	
2-5	5156 (43%)	3992 (42%)	1164 (48%)	
6-10	1476 (12%)	1124 (12%)	352 (14%)	
≥11	307 (3%)	224 (2%)	83 (3%)	
Dialysis Modality, n (%)				0.0528
Hemodialysis	10501 (88%)	8332 (88%)	2169 (89%)	
Peritoneal dialysis	1451 (12%)	1183 (12%)	268 (11%)	
Comorbid conditions, n (%)				
CHF	6347 (53%)	4939 (52%)	1408 (58%)	<0.0001
COPD	1181 (10%)	914 (10%)	267 (11%)	0.0463
CVA / TIA	1740 (15%)	1363 (14%)	377 (16%)	0.1527
Cancer	644 (5%)	497 (5%)	147 (6%)	0.1147
Diabetes Mellitus	8963 (75%)	7354 (77%)	1609 (66%)	<0.0001
Dysrhythmia	5018 (42%)	3883 (41%)	1135 (47%)	<0.0001
Hypertension	11637 (97%)	9273 (98%)	2364 (97%)	0.2138
Liver disease	509 (4%)	366 (4%)	143 (6%)	<0.0001
PVD	3352 (28%)	2726 (29%)	626 (26%)	0.0037
CLI	465 (4%)	377 (4%)	88 (4%)	0.4238
Mean Elixhauser Comorbidity Index, (SD)	6.0 (2.0)	5.9 (1.9)	6.3 (2.0)	<0.0001

CABG = coronary artery bypass graft; CAD = coronary artery disease; CHF = congestive heart failure; CLI = critical limb ischemia; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; ESKD = end-stage kidney disease; IMA = internal mammary artery; PVD = peripheral vascular disease; SD = standard deviation; TIA = transient ischemic attack.

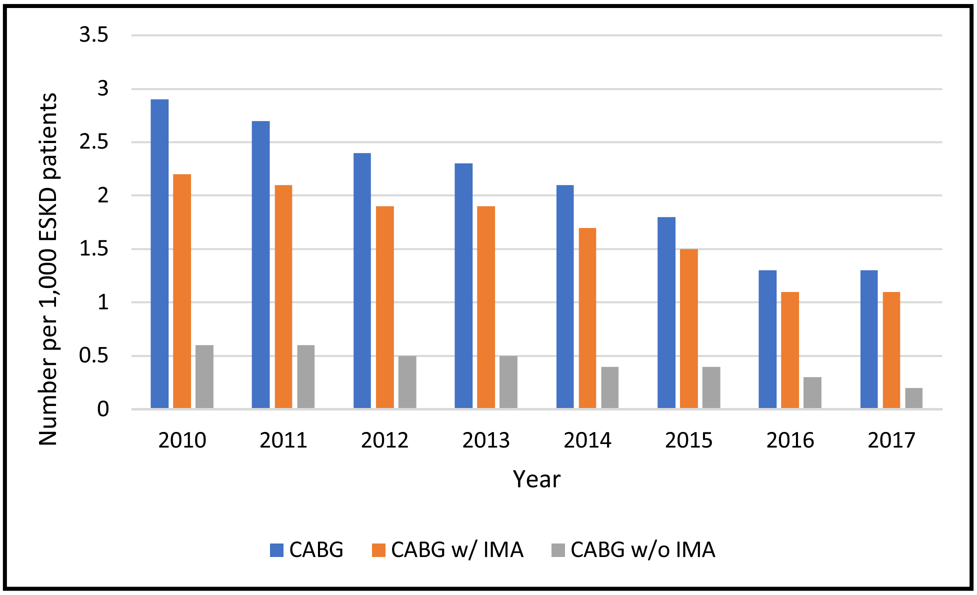

Figure 2. Overall trend of CABG and CABG w/ or w/o IMA graft in patients with ESKD with stable CAD from the years 2010 to 2017. w/ = with; w/o = without.

Table 2
Trends of in-hospital, 30-day, 1-year and 5-year mortality, and 1-year repeat revascularization rates in ESKD patients with stable CAD undergoing CABG during the years 2010-2017

	Overall	2010	2011	2012	2013	2014	2015	2016	2017	p-value
In-hospital mortality	5.9%	6.4%	7.3%	5.5%	5.4%	5.7%	6.8%	4.6%	4.7%	0.01
30-day mortality	6.9%	6.6%	8.1%	6.9%	6.6%	6.6%	8%	5.5%	5.7%	0.14
1-year mortality	22.8 %	24.5%	25.9%	23.3%	21.2%	22.6%	25.6%	16.8%	18.5%	<0.001
5-year mortality	66.2%	67.2%	66.3%	66.2%	65.1%	–	–	–	–	0.1950
1-year repeat revascularization	4.3%	5.2%	3.6%	4.0%	4.4%	4.4%	4.1%	5.1%	3.9%	0.75

CABG = coronary artery bypass graft; CAD = coronary artery disease; ESKD = end-stage kidney disease.

representation. Thus, there is no good evidence to guide the revascularization decisions for patients with ESKD with stable CAD. The only RCT to assess an early revascularization strategy to medical therapy in patients with ESKD was the ISCHEMIA-CKD (International Study of Comparative Health Effectiveness with Medical and Invasive Approaches- Chronic Kidney Diseases).[7] Although it is not truly a study of CABG because only 15% in the invasive strategy arm underwent CABG because the rest underwent percutaneous coronary intervention, the study found no benefit of an early invasive versus conservative therapy in terms of mortality or cardiovascular mortality or myocardial infarction. Thus, this is a data-poor area, and revascularization for stable CAD is, at best, controversial in patients with ESKD.[13] Furthermore, patients with ESKD have high periprocedural mortality from CABG because of their overall high-risk state, making surgical revascularization decisions even more challenging.[6]

The trends in CABG in patients with ESKD had been increasing from years 1988 to 2003, despite the increasing co-morbidities and perioperative mortality.[14] Thus, the finding in our study of a significant decrease in CABG over the years studied is, in fact, reassuring given the lack of evidence for significant benefit from surgical revascularization. These findings are also in line with a previous report by Shroff et al[6] from the USRDS (2004 to 2009) that also showed a decreasing number of overall revascularization procedures, although the numbers of CABG per year remained stable.

As mentioned before, previous studies have demonstrated that the perioperative mortality and short-term mortality in patients with ESKD who underwent CABG is several folds higher than those without ESKD.[15] A study from the USRDS from years 1978 to 1995 found the in-hospital mortality to be 12.5%.[5] A subsequent analysis from the USRDS encompassing the years 2004 to 2009 showed the in-hospital mortality to be 8.2%.[6] The in-hospital mortality rate of 5.9% in our study from years 2010 to 2017 reflects a continued improvement in outcomes in this high-risk population and is encouraging. A caveat is that in previous studies, all CABG procedures were included and not just those performed for stable CAD. We found a consistent decrease in mortality over the study period, with an in-hospital mortality of 4.4% in 2017. The exact reason for these outcomes is speculative but is likely related to the more frequent use of IMA than previous decades, better overall care of these patients in the perioperative period, and likely more judicious patient selection. Although lower than previous years, this 4.4% rate is still almost 3 times higher than the current 1.8% in-hospital mortality reported nationally in the 2021 Society of Thoracic Surgery annual report.[16]

The 1-year and 5-year survival rates of 77% and 35% were dismal, similar to the survival rates of 73% and 32% reported in patients with stable CAD with ESKD from the USRDS 2004 to 2009.[8] Patients who received an IMA graft did better than those who did not receive an IMA graft. The mortality and patency benefits of an IMA graft over saphenous venous grafts have been consistently demonstrated in patients with non-ESKD.[17,18] This likely stems from the lower susceptibility of IMA grafts to atherosclerotic disease and is also associated with a slower progression of native

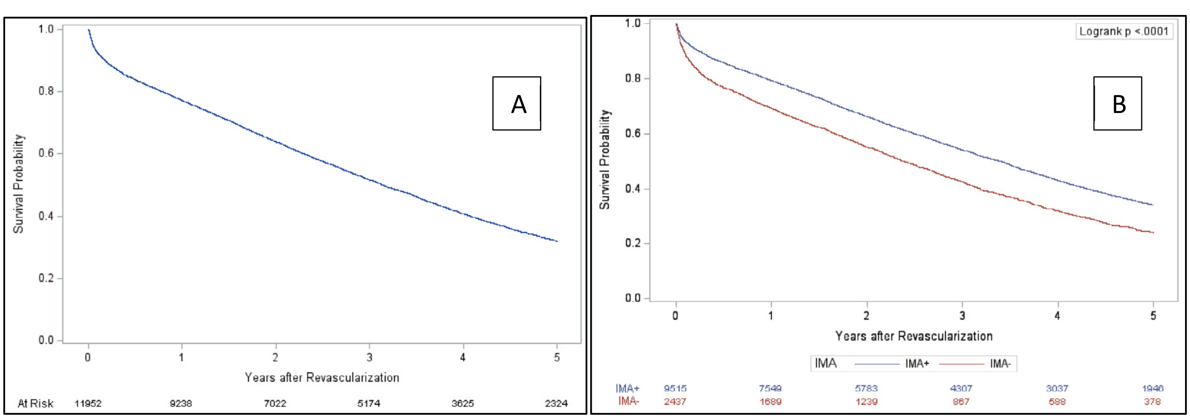

Figure 3. (*A*) Kaplan−Meier survival curve for patients with ESKD receiving CABG for stable CAD. (*B*) Kaplan−Meier survival curve for CABG with and without IMA graft during the study period (log-rank p <0.0001).

atherosclerotic disease than venous grafts.[19] Several structural and molecular characteristics of the IMA make it resistant to atherosclerosis, including fewer fenestrations of the endothelium and decreased permeability and production of chemical factors, such as endothelial nitric oxide, and antithrombotic molecules, such as heparin. These factors limit the deposition of lipoproteins in the arterial wall, limiting atherosclerosis. Our findings demonstrate this benefit in patients with ESKD in recent years and confirm similar findings from previous studies.[6,15] Shroff et al[6] reported the 1- and 5-year survival of 72% and 30% in patients with an IMA graft versus 64% and 24% in those who did not receive a left IMA graft. IMA graft use continues to improve, with almost 80% receiving IMA compared with 2004 to 2009, where IMA was used in 73% of patients. In addition to having a greater risk for coronary disease, patients with ESKD may have an arterial−venous fistula that creates a shunt in the upper extremity. The possibility of altered blood flow through the IMA graft from this this arterial−venous fistula is there but does not seem to affect the left IMA function because these patients have better outcomes.

The findings of a relatively low post-CABG 1-year incidence of AMI (8.4%) and repeat revascularization rate (4.2%) but a very high 1-year mortality rate (22.8%) are consistent with previous knowledge that a significant number of patients with ESKD and CAD likely die from non-AMI−related causes such as arrhythmic sudden cardiac death.[10,20,21]

Our study results should be interpreted understanding the limitation of an observational, administrative database study. Although the USRDS data have been extensively reported and validated, it is subject to coding errors and unmeasured confounders. Furthermore, we did not have key clinical information such as symptoms, extent of ischemia, left ventricular systolic function, or coronary anatomy or even the patient's functional status. All these factors impact revascularization decisions and can be best addressed in an RCT. However, given the paucity of current information for well-conducted clinical trials on the subject, our study provides clinically useful information for the clinicians taking care of patients with ESKD with stable CAD.

In conclusion, in patients with ESKD on dialysis with stable CAD, there has been a decrease in the number of CABG procedures performed nationally over the 8-year study period. The in-hospital mortality has also decreased significantly, although is still several folds higher than in the general population who underwent CABG. The 1-year and long-term mortality remains high but has been decreasing over the years. In view of the uncertain benefit of revascularization in stable CAD in ESKD, these outcomes results re-emphasize the need for caution and individualization of revascularization decisions in consultations with patients.

Declaration of Competing Interest

The authors have no competing interest to declare. The data reported here have been supplied by the United States Renal Data System. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the US government.

Authors' Contributions

Drs. Vasudeva and Mehta were responsible for designing the study, interpretation of data, drafting of manuscript, critical revision of manuscript, and final approval of manuscript. Dr. Chan was responsible for data analysis, critical revision of manuscript, and final approval of manuscript. Drs. Majmundar, Yarlagadda, Downey, Daon, Muehlebach, Danter, Zorn, Mark Wiley, Tadros, and Hockstad were responsible for the critical revision of manuscript and final approval of manuscript. Dr. Gupta was responsible for conceptualization and design of study, interpretation of data, drafting of manuscript, critical revision of manuscript, and final approval of manuscript.

Data Availability

The data underlying this article are available in the USRDS. The data sets were derived from sources in the public domain: https://www.niddk.nih.gov/about-niddk/strategic-plans-reports/usrds/for-researchers/simple-data-requests.

Ethics Approval

This project was originally reviewed and approved by the University of Kansas Medical Center Human Research Protection Program for Flexible Institutional Review Board Review on 11/23/2021 (IRB no. STUDY00148033). No patient consent was required for this study. USRDS has approved this data/study to be published.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2023.10.004.

1. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases. 2021 Annual data report: epidemiology of kidney disease in the United States. Available at: https://usrds-adr.niddk.nih.gov/2021. Accessed on December 23, 2022.
2. Bhatti NK, Karimi Galougahi K, Paz Y, Nazif T, Moses JW, Leon MB, Stone GW, Kirtane AJ, Karmpaliotis D, Bokhari S, Hardy MA, Dube G, Mohan S, Ratner LE, Cohen DJ, Ali ZA. Diagnosis and management of cardiovascular disease in advanced and end-stage renal disease. *J Am Heart Assoc* 2016;5:e003648.
3. Schwarz U, Buzello M, Ritz E, Stein G, Raabe G, Wiest G, Mall G, Amann K. Morphology of coronary atherosclerotic lesions in patients with end-stage renal failure. *Nephrol Dial Transplant* 2000;15:218–223.
4. London GM, Guérin AP, Marchais SJ, Métivier F, Pannier B, Adda H. Arterial media calcification in end-stage renal disease: impact on all-cause and cardiovascular mortality. *Nephrol Dial Transplant* 2003;18:1731–1740.
5. Herzog CA, Ma JZ, Collins AJ. Long-term outcome of dialysis patients in the United States with coronary revascularization procedures. *Kidney Int* 1999;56:324–332.
6. Shroff GR, Solid CA, Herzog CA. Long-term survival and repeat coronary revascularization in dialysis patients after surgical and

percutaneous coronary revascularization with drug-eluting and bare metal stents in the United States. *Circulation* 2013;127:1861–1869.

7. Bangalore S, Maron DJ, O'Brien SM, Fleg JL, Kretov EI, Briguori C, Kaul U, Reynolds HR, Mazurek T, Sidhu MS, Berger JS, Mathew RO, Bockeria O, Broderick S, Pracon R, Herzog CA, Huang Z, Stone GW, Boden WE, Newman JD, Ali ZA, Mark DB, Spertus JA, Alexander KP, Chaitman BR, Chertow GM, Hochman JS, ISCHEMIA-CKD Research Group. Management of coronary disease in patients with advanced kidney disease. *N Engl J Med* 2020;382:1608–1618.
8. Shroff GR, Solid CA, Herzog CA. Impact of acute coronary syndromes on survival of dialysis patients following surgical or percutaneous coronary revascularization in the United States. *Eur Heart J Acute Cardiovasc Care* 2016;5:205–213.
9. Go AS, Chertow GM, Fan D, McCulloch CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. *N Engl J Med* 2004;351:1296–1305.
10. Wanner C, Amann K, Shoji T. The heart and vascular system in dialysis. *Lancet* 2016;388:276–284.
11. Shaw LJ, Berman DS, Maron DJ, Mancini GB, Hayes SW, Hartigan PM, Weintraub WS, O'Rourke RA, Dada M, Spertus JA, Chaitman BR, Friedman J, Slomka P, Heller GV, Germano G, Gosselin G, Berger P, Kostuk WJ, Schwartz RG, Knudtson M, Veledar E, Bates ER, McCallister B, Teo KK, Boden WE, COURAGE Investigators. Optimal medical therapy with or without percutaneous coronary intervention to reduce ischemic burden: results from the Clinical Outcomes Utilizing revascularization and Aggressive Drug Evaluation (COURAGE) trial nuclear substudy. *Circulation* 2008;117:1283–1291.
12. BARI 2D Study Group, Frye RL, August P, Brooks MM, Hardison RM, Kelsey SF, MacGregor JM, Orchard TJ, Chaitman BR, Genuth SM, Goldberg SH, Hlatky MA, Jones TL, Molitch ME, Nesto RW, Sako EY, Sobel BE. A randomized trial of therapies for type 2 diabetes and coronary artery disease. *N Engl J Med* 2009;360:2503–2515.
13. Sarnak MJ, Amann K, Bangalore S, Cavalcante JL, Charytan DM, Craig JC, Gill JS, Hlatky MA, Jardine AG, Landmesser U, Newby LK, Herzog CA, Cheung M, Wheeler DC, Winkelmayer WC, Marwick TH, Conference Participants. Chronic kidney disease and coronary artery disease: JACC state-of-the-art review. *J Am Coll Cardiol* 2019;74:1823–1838.
14. Parikh DS, Swaminathan M, Archer LE, Inrig JK, Szczech LA, Shaw AD, Patel UD. Perioperative outcomes among patients with end-stage renal disease following coronary artery bypass surgery in the USA. *Nephrol Dial Transplant* 2010;25:2275–2283.
15. Shilane D, Hlatky MA, Winkelmayer WC, Chang TI. Coronary artery bypass graft type and outcomes in maintenance dialysis. *J Cardiovasc Surg (Torino)* 2015;56:463–471.
16. Bowdish ME, D'Agostino RS, Thourani VH, Schwann TA, Krohn C, Desai N, Shahian DM, Fernandez FG, Badhwar V. STS Adult Cardiac surgery database: 2021 update on outcomes, quality, and research. *Ann Thorac Surg* 2021;111:1770–1780.
17. Zeff RH, Kongtahworn C, Iannone LA, Gordon DF, Brown TM, Phillips SJ, Skinner JR, Spector M. Internal mammary artery versus saphenous vein graft to the left anterior descending coronary artery: prospective randomized study with 10-year follow-up. *Ann Thorac Surg* 1988;45:533–536.
18. Loop FD. Internal-thoracic-artery grafts. Biologically better coronary arteries. *N Engl J Med* 1996;334:263–265.
19. Otsuka F, Yahagi K, Sakakura K, Virmani R. Why is the mammary artery so special and what protects it from atherosclerosis? *Ann Cardiothorac Surg* 2013;2:519–526.
20. Makar MS, Pun PH. Sudden cardiac death among hemodialysis patients. *Am J Kidney Dis* 2017;69:684–695.
21. Genovesi S, Boriani G, Covic A, Vernooij RWM, Combe C, Burlacu A, Davenport A, Kanbay M, Kirmizis D, Schneditz D, van der Sande F, Basile C, EUDIAL Working Group of ERA-EDTA. Sudden cardiac death in dialysis patients: different causes and management strategies. *Nephrol Dial Transplant* 2021;36:396–405.