Chronic kidney disease, risk of readmission, and progression to end-stage renal disease in 519,387 patients undergoing coronary artery bypass grafting

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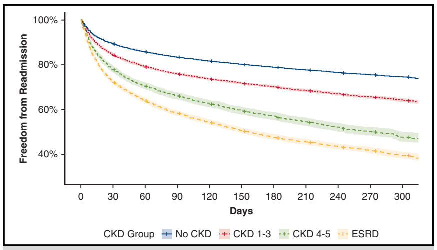
ABSTRACT

Objective: The association between chronic kidney disease and adverse outcomes after coronary artery bypass grafting is well established; in contrast, the association between chronic kidney disease and readmission has been less thoroughly investigated. We hypothesized that patients at higher chronic kidney disease stages have greater risk of readmission, poorer operative outcomes, and greater hospitalization cost.

Methods: Using the 2016-2018 Nationwide Readmissions Database, we identified 519,387 patients who underwent isolated coronary artery bypass grafting. Patients were stratified by chronic kidney disease stage based on International Classification of Diseases 10th Revision classification. Multivariable logistic regression was used to assess risk factors for in-hospital mortality and 90-day readmission.

Results: Hospital readmission, in-hospital mortality, and cost progressively increased with worsening chronic kidney disease stage; patients with end-stage renal disease had the highest in-hospital mortality rate (7.2%), hospitalization costs ($59,616) ($P < .001$), and 90-day readmission rate (40%) ($P < .001$). Chronic kidney disease stage greater than 3 was associated with in-hospital mortality (odds ratio, 1.56, 95% confidence interval, 1.40-1.73; $P < .001$) and 90-day readmission (odds ratio, 1.66, 95% confidence interval, 1.56-1.76; $P < .001$). At 30 days after discharge, new-onset dialysis dependence was more frequent in patients readmitted with chronic kidney disease 4 to 5 (8.9%; n = 1495) than in patients with chronic kidney disease 1 to 3 (1.4%; n = 8623) and patients without chronic kidney disease (0.3%; n = 38,885). At 90 days after discharge, dialysis dependence increased to 11.1% (n = 1916) in readmitted patients with chronic kidney disease 4 to 5 but remained stable for patients with chronic kidney disease 1 to 3 (1.4%; n = 10,907) and patients without chronic kidney disease (0.3%; n = 50,200).

Conclusions: Chronic kidney disease stage is strongly associated with mortality, new-onset dialysis dependence, readmission, and higher cost after coronary artery bypass grafting. Patients with chronic kidney disease 4 and 5 and patients with end-stage renal disease are readmitted at the highest rates. Although further research is needed, a targeted approach may reduce costly readmissions and improve outcomes after coronary artery bypass grafting in patients with chronic kidney disease. (JTCVS Open 2022;12:147-57)



Kaplan–Meier curves show freedom from readmission by CKD severity.

CENTRAL MESSAGE

Patients with CKD are at significantly elevated risk of readmission after CABG.

PERSPECTIVE

CKD is associated with greater risk of readmission after CABG. As CKD disease status progresses, readmission risk and patient outcomes worsen. A targeted approach used throughout the perioperative period should be explored to reduce readmission risk.

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
CKD	= chronic kidney disease
ESRD	= end-stage renal disease
ICD-10	= International Classification of Diseases, Tenth Revision
ICD-10-CM	= International Classification of Diseases, Tenth Revision, Clinical Modification
LOS	= length of stay
NRD	= National Readmissions Database

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Chronic kidney disease (CKD) is a common comorbidity in patients undergoing coronary artery bypass grafting (CABG); in an analysis of approximately 500,000 patients who underwent CABG, 28% had moderate or severe CKD at the time of surgery.[1] Compared with the general population, patients with CKD are 3 times more likely to undergo CABG, 4 times more likely to experience a myocardial infarction or heart failure, and 2 times as likely to have a stroke or other major neurologic event.[2] Among patients undergoing CABG, those with CKD and especially those with end-stage renal disease (ESRD) have greater mortality and perioperative morbidity risk.[1] Given the significant morbidity and mortality associated with CKD and the disproportionate need for CABG in these patients, we sought to evaluate the risk of readmission and the risk of progression of renal disease after CABG in this cohort of patients.

Readmission after CABG is common; 13% to 15% of all patients are readmitted within 30 days.[3,4] Previous studies have associated renal disease with 30-day readmission; however, intermediate (90-day) and longer-term (1-year) risk of readmission have not been investigated.[4] Further, the current literature is largely limited to reports of poorer outcomes with renal disease broadly; to our knowledge, there has been no focused analysis of readmission outcomes for patients with CKD after CABG.

In this study, we aimed to characterize adverse outcomes in patients with CKD who undergo CABG. We hypothesized that patients with more advanced CKD have worse postoperative outcomes, are more likely to have index readmission, have greater resource use, and have a greater need for dialysis after CABG.

MATERIALS AND METHODS

Data Source

We used data from the Nationwide Readmissions Database (NRD), which samples hospitals from 28 states and links patient admissions to allow calculation of readmissions and other outcomes. The NRD uses deidentified patient and hospital information in compliance with Health Insurance Portability and Accountability Act guidelines; consequently, Institutional Review Board approval and informed patient consent were not required for this study. The NRD uses a clustered, poststratified design to allow calculation of national estimates, and we accounted for the complex survey design of the NRD in all aspects of the study.[5]

Study Cohort

We queried the NRD between January 1, 2016, and December 31, 2018, to identify adults who underwent isolated CABG. We identified the CKD stage of the patients and used the previously established Kidney Disease: Improving Global Outcomes classification system to separate them into 4 groups: no CKD, CKD stages 1 to 3, CKD stages 4 and 5, and ESRD.[6] We used International Classification of Diseases, 10th Revision (ICD-10) Procedural Classification System codes beginning with 0210 to identify patients who underwent CABG. We used ICD-10-Clinical Modification (ICD-10-CM) codes beginning with N18 to identify CKD stage. Patients who had more than 1 CKD staging during the index admission were grouped according to the highest CKD stage assigned on that admission. Patients with ICD-10-CM code N18.6 (ESRD) or Z99.2 (dependence on renal dialysis) were put in the ESRD group. Patients with the ICD-10 code N18.9 (CKD, unspecified) were excluded from analysis. A complete list of the ICD-10 codes used for inclusion, exclusion, and grouping is provided in Table E1.

Patient and Hospital Characteristics

Many patient and hospital characteristics, including age, sex, elective admission status, primary payer for admission, and hospital characteristics (bed size, geographic location, and teaching status), were provided in the NRD and used as is. Elixhauser comorbidities were derived from ICD-10-CM codes as previously reported.

Outcomes

Our primary outcome was readmission within 90 days after CABG. Our secondary end points were in-hospital mortality, the need for new dialysis at readmission after CABG, and hospitalization costs. In-hospital mortality, length of stay (LOS), and discharge disposition for each admission were calculated from data provided in the NRD. Admission cost was calculated from admission charges by using cost-to-charge ratios provided by the NRD, as is standard practice. Readmission at 30 and 90 days, readmission LOS, readmission mortality, and readmission cost were calculated. Because the NRD captures admissions data separately for each calendar year, for 30-day readmissions, only patients discharged between January 1 and November 30 of each year of the study period were included, and for 90-day readmissions, only patients discharged between January 1 and September 30 were included. Causes of readmission were determined from the primary ICD-10-CM codes present on readmission and were grouped into clinically meaningful categories as previously described.[7]

Statistical Analysis

Analyses were performed with R version 4.1.[8] The R package "survey" was used to account for the clustering, poststratification, and sample weights provided by the NRD for all calculations[9] to generate national estimates. Less than 1% of values from any category were missing. Missing values were replaced with the median value of the overall cohort for continuous variables or the mode for categorical variables. Categorical variables are presented as count (%) and were analyzed by using the chi-square test with Rao-Scott adjustment for complex survey design. Continuous variables are presented as median with interquartile range (IQR) and were analyzed with the Kruskal–Wallis rank-sum test for complex survey design. Multivariable analysis was performed by using binomial logistic regression with complex survey-adjusted modeling. All variables considered in the model are presented in Table E2. Regression results are presented as odds ratio and 95% confidence intervals (CIs) with a P value from a survey-adjusted Wald test. Kaplan–Meier analysis was used to estimate freedom from readmission.

RESULTS

Preoperative Characteristics

Between 2016 and 2018, 519,387 patients underwent CABG: 429,711 (82.7%) had no CKD, 64,481 (12.4%) had stage 1 to 3 CKD, 8286 (1.6%) had stage 4 and 5 CKD, and 16,909 (3.3%) had ESRD (Figure 1, Table 1). Patients with CKD 1 to 3 were oldest (median age, 70 years [IQR, 64-76]), followed by those with CKD 4 and 5 (70 [62-76] years), no CKD (66 [58-72] years), and ESRD (64 [56-70] years; $P < .001$). Patients with CKD 4 and 5 (31.5%) or ESRD (29.5%) were more often female than those with CKD 1 to 3 or no CKD (24.2%; $P < .001$). Patients without CKD were more likely to have private insurance (33.5%) than those with CKD 1 to 3 (19%), CKD 4 and 5 (19%), or ESRD (15.4%; $P < .001$). Conversely, 73.6% of patients with ESRD had Medicare compared with 52.7% of those without CKD (Table 1).

Patients with ESRD had a higher comorbidity burden (median Elixhauser score of 22) than those with CKD 4 and 5 (20), CKD 1 to 3 (16), or no CKD (5; $P < .001$; Table 2). Patients with CKD 4 and 5 had higher rates of congestive heart failure (64.1%), pulmonary circulation disorders (13.3%), liver disease (7.0%), coagulopathy (30.9%), and electrolyte disorders (65.1%) than patients with ESRD or CKD 1 to 3 or lower. Patients without CKD had higher rates of drug abuse (2.7%) and alcohol abuse (3.8%) than those with CKD or ESRD (Table 2).

Index Hospitalization Outcomes

In-hospital mortality and cost were progressively greater at more advanced CKD stages (Table 3). Patients with ESRD had higher rates of in-hospital mortality (7.2%) than those with CKD 4 and 5 (4.7%), CKD 1 to 3 (3.0%), or no CKD (1.5%; $P < .001$). Mean LOS was also greater for patients with ESRD and CKD 4 and 5 (median, 13 [IQR 9-19] days) than for patients with CKD 1 to 3 (10 [7-15] days) or no CKD (7 [5-11] days; $P < .001$). Median hospitalization costs were higher for the ESRD group ($59,616 [42,719-85,120]) than for the CKD 4 and 5 ($54,175 [39,980-74,339]), CKD 1 to 3 ($45,277 [34,038-62,645]), and no CKD ($38,626 [30,458-54,450]) groups ($P < .001$).

Postdischarge Outcomes

Patients with ESRD had higher rates of 30- and 90-day readmission (30-day, 26.7%; 90-day, 40.2%) than patients with CKD 4 and 5 (21.2%; 33.1%) and CKD 1 to 3 (15.1%; 23.5%), and patients with no CKD (10.0%; 15.8%; $P < .001$; Table 3). In patients who were readmitted within 30 days, new-onset dialysis dependence was most frequent in patients with CKD 4 and 5 (8.9%; n = 1495) compared with CKD 1 to 3 (1.4%; n = 8623) and patients with no CKD (0.3%, n = 38,885). The rate of dialysis dependence was even higher in patients with CKD 4 and 5 readmitted within 90 days (11.1%; n = 1916) than in those readmitted within 30 days, but the rate of dialysis dependence for patients with CKD 1 to 3 (1.4%; n = 10,907) and patients without CKD (0.3%; n = 50,200) readmitted within 90 days was similar to the rates in such patients readmitted within 30 days. Additionally, the rates of death on readmission were equivalent between patients with ESRD (3.8%, n = 7208) and patients with CKD 4 and 5 (3.8%, n = 2967); both were greater than the rate for patients with CKD 1 to 3 (2.7%, n = 16,840) and patients with no CKD (1.9%, n = 78,561). By Kaplan–Meier analysis, freedom from readmission at 1 year was lowest for the ESRD group, followed by the CKD 4 and 5, CKD 1 to 3, and no CKD groups. By 300 days, 60% of patients with ESRD were

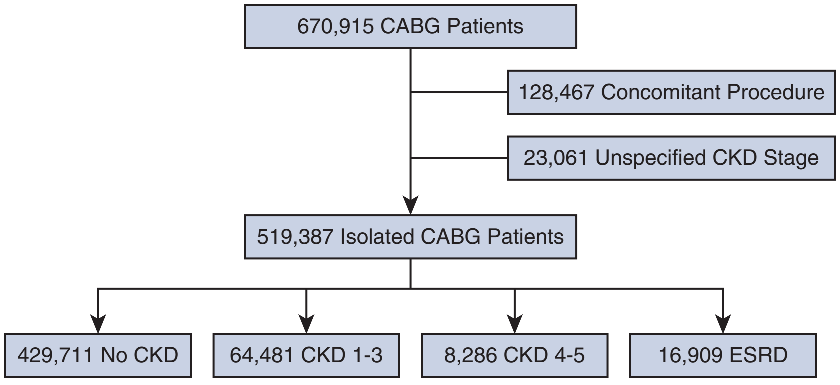


FIGURE 1. STROBE diagram illustrating the classification of the patient cohort. *CABG*, Coronary artery bypass grafting; *CKD*, chronic kidney disease; *ESRD*, end-stage renal disease.

TABLE 1. Characteristics of patients with chronic kidney disease who underwent coronary artery bypass grafting

Characteristic	Overall (n = 519,387)	No CKD (n = 429,711)	CKD 1-3 (n = 64,481)	CKD 4-5 (n = 8286)	ESRD (n = 16,909)	*P* value*
Age, mean ± SD, y	66 ± 10	65 ± 10	70 ± 9	69 ± 10	63 ± 10	<.001
Female, %	127,395 (24.5%)	104,205 (24.2%)	15,589 (24.2%)	2611 (31.5%)	4991 (29.5%)	<.001
Elective, %	237,828 (45.9%)	201,586 (47.1%)	27,237 (42.3%)	2963 (35.8%)	6041 (35.8%)	<.001
Income quartile, %						<.001
1	143,565 (28.1%)	118,321 (28.0%)	17,344 (27.3%)	2369 (29.0%)	5532 (33.3%)	
2	148,050 (28.9%)	122,731 (29.0%)	18,473 (29.1%)	2282 (27.9%)	4564 (27.4%)	
3	129,226 (25.3%)	106,742 (25.2%)	16,371 (25.8%)	2122 (26.0%)	3991 (24.0%)	
4	90,709 (17.7%)	75,402 (17.8%)	11,369 (17.9%)	1396 (17.1%)	2542 (15.3%)	
Primary payor, %						<.001
Medicaid	38,472 (7.4%)	32,800 (7.6%)	3718 (5.8%)	603 (7.3%)	1351 (8.0%)	
Medicare	289,757 (55.9%)	226,008 (52.7%)	45,566 (70.8%)	5749 (69.4%)	12,434 (73.6%)	
Private insurance	159,950 (30.8%)	143,572 (33.5%)	12,207 (19.0%)	1573 (19.0%)	2598 (15.4%)	

CKD, Chronic kidney disease; *ESRD*, end-stage renal disease; *SD*, standard deviation. *Kruskal–Wallis rank-sum test for complex survey samples; chi-square test with Rao & Scott's second-order correction.

readmitted, compared with 50% of patients with CKD 4 and 5, 35% of patients with CKD 1 to 3, and 25% of patients with no CKD (Figure 2). Multivariable regression identified 4 variables that were associated with both in-hospital mortality and 90-day readmission: CKD stage greater than 3, female sex, Medicaid as primary payer, and age greater than 65 years (Figure 3; Table E2). Analysis of readmission causes found that the most common reasons for readmission were cardiovascular (32%), followed by infection (18%) (Figure 4).

DISCUSSION

Our retrospective analysis of 519,387 patients who underwent CABG with or without CKD produced 3 key findings. First, the 90-day readmission rate was significantly higher in patients with ESRD (40%) and patients with CKD 4 and 5 (33%) than in patients with less severe CKD or no CKD. Second, in-hospital mortality was approximately 5 times greater in patients with ESRD than in patients without CKD. Third, patients with CKD 4 and 5 were 35 times more likely than

TABLE 2. Prevalence of Elixhauser comorbidities in patients with chronic kidney disease who underwent coronary artery bypass grafting

Characteristic	Overall (n = 519,387)	No CKD (n = 429,711)	CKD 1-3 (n = 64,481)	CKD 4-5 (n = 8286)	ESRD (n = 16,909)	*P* value*
Elixhauser score, median (IQR)	8 (−1-16)	5 (−1-13)	16 (8-24)	20 (12-28)	22 (13-28)	<.001
Congestive heart failure, %	178,858 (34.4%)	31,948 (49.5%)	5332 (64.4%)	10,846 (64.1%)	130,732 (30.4%)	<.001
Arrhythmia, %	241,818 (46.6%)	35,302 (54.7%)	4465 (53.9%)	8428 (49.8%)	193,623 (45.1%)	<.001
Valve disease, %	83,324 (16.0%)	13,342 (20.7%)	1879 (22.7%)	3584 (21.2%)	64,519 (15.0%)	<.001
Pulmonary circulation disorder, %	27,329 (5.3%)	5505 (8.5%)	1006 (12.1%)	2255 (13.3%)	18,563 (4.3%)	<.001
Peripheral artery disease, %	78,677 (15.1%)	13,518 (21.0%)	1897 (22.9%)	3588 (21.2%)	59,674 (13.9%)	<.001
Hypertension, %	454,340 (87.5%)	61,600 (95.5%)	7967 (96.2%)	16,575 (98.0%)	368,198 (85.7%)	<.001
Chronic obstructive pulmonary disease, %	116,853 (22.5%)	16,180 (25.1%)	2079 (25.1%)	3491 (20.6%)	95,102 (22.1%)	<.001
Diabetes mellitus, all, %	247,013 (47.6%)	40,593 (63.0%)	6094 (73.5%)	13,028 (77.1%)	187,299 (43.6%)	<.001
Liver disease, %	18,132 (3.5%)	2845 (4.4%)	415 (5.0%)	1191 (7.0%)	13,681 (3.2%)	<.001
Coagulopathy, %	108,948 (21.0%)	16,946 (26.3%)	2133 (25.7%)	5229 (30.9%)	84,640 (19.7%)	<.001
Electrolyte disorder, %	183,642 (35.4%)	30,085 (46.7%)	5244 (63.3%)	11,012 (65.1%)	137,300 (32.0%)	<.001
Alcohol abuse, %	19,678 (3.8%)	1748 (2.7%)	145 (1.7%)	225 (1.3%)	17,561 (4.1%)	<.001
Drug abuse, %	13,983 (2.7%)	1283 (2.0%)	154 (1.9%)	368 (2.2%)	12,178 (2.8%)	<.001

CKD, Chronic kidney disease; *ESRD*, end-stage renal disease; *IQR*, interquartile range. *Kruskal–Wallis rank-sum test for complex survey samples; chi-square test with Rao & Scott's second-order correction.

TABLE 3. Outcomes after coronary artery bypass grafting stratified by severity of chronic kidney disease

Characteristic	No CKD (n = 387,054)	CKD 1-3 (n = 57,095)	CKD 4-5 (n = 7050)	ESRD (n = 14,307)	*P* value
In-hospital mortality, n/N (%)	6588/429,711 (1.5%)	1915/64,474 (3.0%)	388/8285 (4.7%)	1214/16,902 (7.2%)	<.001
LOS, median (IQR)	7 (5-11)	10 (7-15)	13 (9-20)	13 (8-21)	<.001
Index hospitalization cost (USD), median (IQR)	38,626 (29,718-51,966)	45,277 (34,038-62,645)	54,175 (39,980-74,339)	59,616 (42,719-85,120)	<.001
Disposition, %					<.001
Home health care	42.3	41.8	38.4	37.4	
Routine	42.2	29.3	25.5	24.9	
Skilled nursing facility or intermediate care facility	15.0	28.0	34.5	36.0	
Short-term hospital	0.4	0.7	1.3	1.3	
30-d readmissions, %	10.0	15.1	21.2	26.7	<.001
90-d readmissions, %	15.8	23.5	33.1	40.2	<.001
Died on readmission, n/N (%)	1483/78,561 (1.9%)	462/16,840 (2.7%)	112/2967 (3.8%)	277/7208 (3.8%)	<.001
Readmission LOS, median (IQR)	3 (2-6)	4 (2-7)	4 (2-8)	4 (2-8)	<.001
Readmission cost, median (IQR)	8747 (5034-16,386)	9111 (5326-17,431)	10,063 (5713-19,399)	11,077 (6272-21,198)	<.001
Elective readmission, n/N (%)	12,497/78,474 (15.9%)	2157/16,805 (12.8%)	312/2966 (10.5%)	566/7200 (7.9%)	<.001

CKD, Chronic kidney disease; *ESRD*, end-stage renal disease; *LOS*, length of stay; *IQR*, interquartile range.

patients without CKD to become dialysis-dependent within 90 days of discharge.

Given the high rate of readmission after CABG in all patients, estimated by a recent meta-analysis to be approximately 1 in 8 patients within 30 days, readmission risk assessment and modification are critical in patients with CKD undergoing CABG.[4] Our results showed that patients without CKD had a post-CABG 30-day readmission rate of 10%, and with each advancement of CKD stratification, the risk of readmission increased uniformly by approximately 5%. More important, the 90-day rate of readmission was approximately 50% greater than the 30-day rate in all categories of CKD/ESRD. Medicare's Bundle Payment of Care Improvement focuses on 90-day outcomes, including readmission, so this information is vital to collect because the cost burden of readmissions falls on hospitals.[10]

It is notable that 11% of patients with CKD 4 and 5 were readmitted within 90 days and were on dialysis. The true percentage is probably higher, because patients who required dialysis on index admission would have been characterized as having ESRD, and the database did not distinguish between dialysis for preoperative ESRD and dialysis for postoperative acute kidney injury.[11] Other series have shown that typically, within a 1.5-year median follow-up period, approximately 10% of patients with CKD 4 and 5 progress to dialysis.[11] Notably, nephrology care can delay the progression to dialysis dependence by more than 1 year in patients with CKD 5.[12]

Beyond readmissions, patients with CKD also had significantly poorer postoperative outcomes at the index operation than patients with no CKD. Previous studies have shown significantly elevated mortality among patients readmitted to the hospital after major surgery.[13] Our study showed that patients with ESRD have a 5-fold higher mortality rate than patients with no kidney disease during their index hospitalization; furthermore, during index readmission, patients with CKD 4 and 5 and patients with ESRD had twice the mortality rate of patients without CKD.

CKD disproportionately affects patients of low socioeconomic status.[14] The results of our study showed that most patients with CKD used Medicare to pay for their index admission, and approximately one-third of patients with CKD lived in ZIP codes in the bottom quartile of income in the United States. The finding underscores how the burden of CKD in patients who undergo CABG probably has a significant socioeconomic component that influences readmission and outcomes. These patients can especially benefit from preventive measures that slow the progression of CKD. Such measures include controlling blood pressure with medications that block the renin-angiotensin axis, controlling blood glucose, correcting acidosis, and preventive screening in patients who are at higher risk of CKD, such

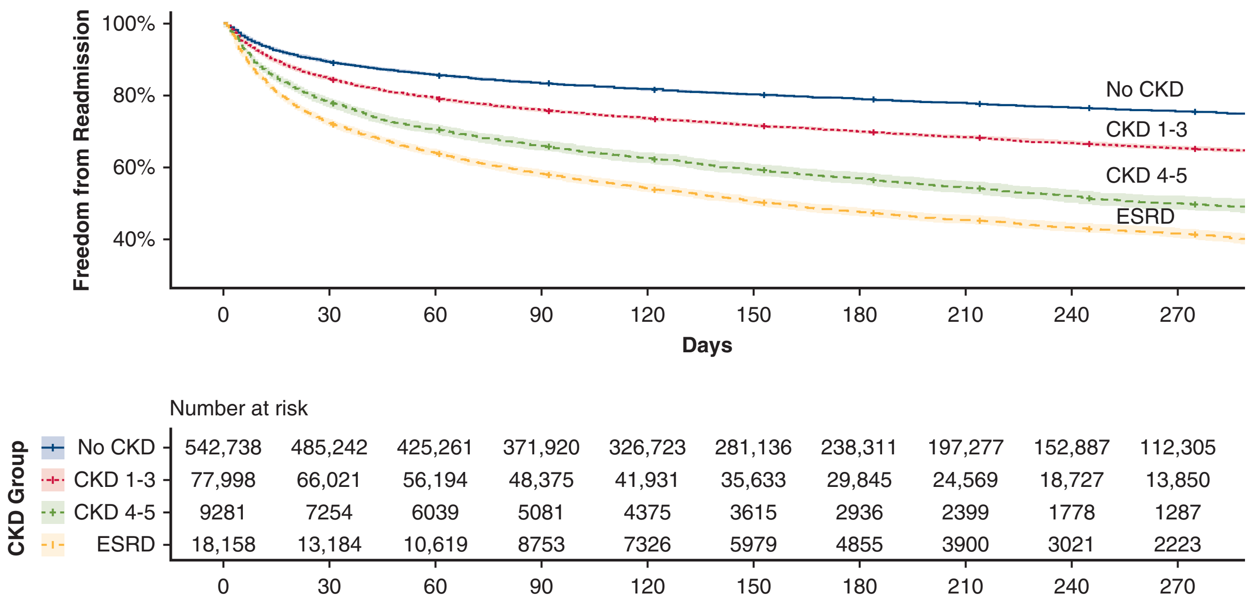


FIGURE 2. Kaplan–Meier curves showing freedom from readmission by CKD severity (95% CI). *CKD*, Chronic kidney disease; *ESRD*, end-stage renal disease.

as patients with diabetes.[15] Additionally, although it is well established that patients of lower socioeconomic status have a greater risk of disorders that contribute to CKD, these patients subsequently have less access to renal replacement therapy, which probably contributes to poorer outcomes.[16]

Further, the economic burden of readmission after CABG remains substantial. A previous study evaluating readmissions after CABG between 2010 and 2014 found that the cost of readmission was on average $13,499, with a net annual cost of more than $250 million.[17,18] This finding was in line with our results, which showed that the cost of readmission ranged between $5034 and $21,198 and was proportionally greater at more advanced CKD stages.

Optimal perioperative management of patients with CKD is important for cardiologists, nephrologists, surgeons, and critical care specialists in all phases of care.[14] Recent studies have demonstrated that preoperative use of aspirin is renally

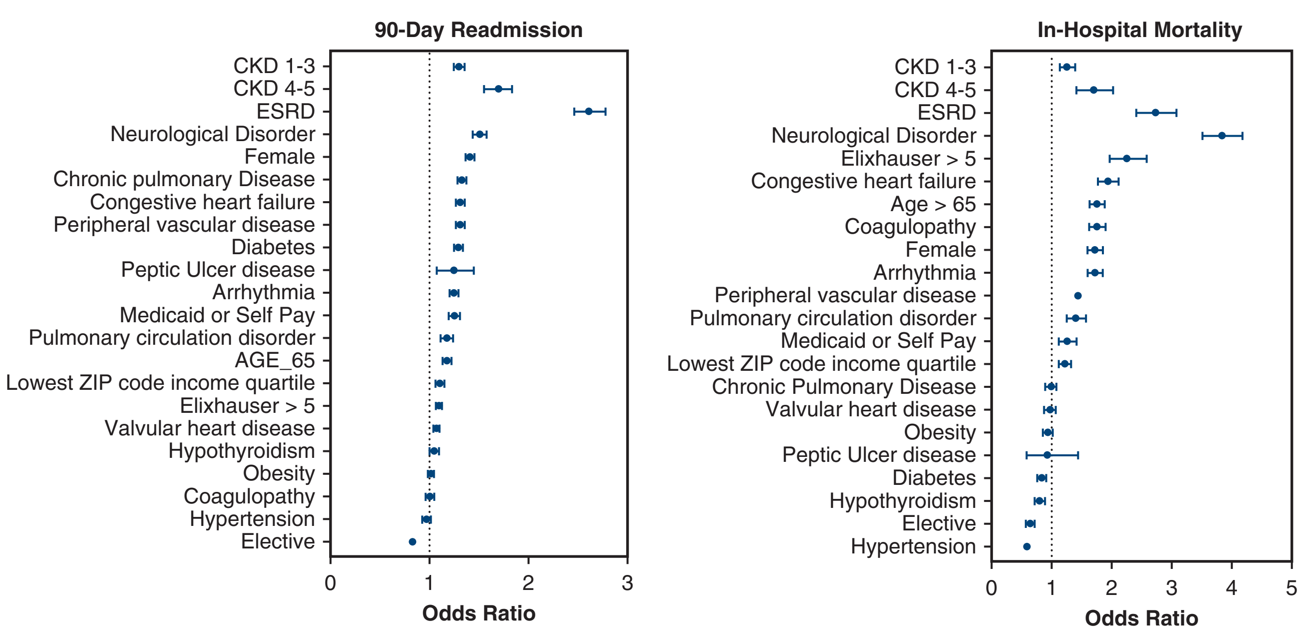


FIGURE 3. Forest plot analysis of 90-day readmissions and in-hospital mortality (95% CI). *CKD*, Chronic kidney disease; *ESRD*, end-stage renal disease.

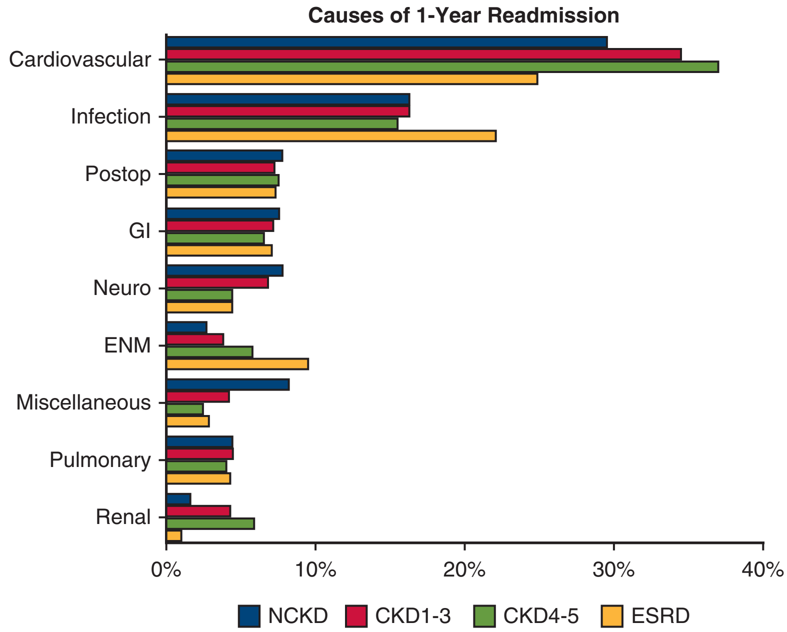


FIGURE 4. Causes of 1-year readmission stratified by cause of disease. *GI*, Gastrointestinal disorder; *ENM*, endocrine, nutrition, and metabolic disorders; *NCKD*, no chronic kidney disease; *CKD*, chronic kidney disease; *ESRD*, end-stage renal disease.

protective and reduces mortality risk, especially in patients with CKD.[19] In addition, evidence suggests that statins reduce both the need for renal replacement therapy and mortality after CABG.[20] Although mineralocorticoid receptor antagonists reduce cardiovascular mortality risk, their preoperative use in patients with CKD has not been shown to be renally protective and is associated with the development of a low cardiac output state.[21] It may be prudent to discontinue the use of these drugs before CABG in patients with CKD. Finally, in patients on dialysis, optimizing anemia and nutrition has been shown to reduce the risk of readmission.[22] Dedicated focus on each of these aspects of preoperative care may improve outcomes.

Despite the continuously growing prevalence of CKD,[1] few studies have attempted to identify optimal treatment strategies for these patients. According to the most recent American College of Cardiology/American Heart Association joint guidelines for coronary revascularization,[23] data on optimal treatment strategies for patients with CKD remain scarce because, traditionally, these patients have been excluded from randomized controlled trials. Still, some studies have attempted to answer this question. In a review of 219 patients with an ipsilateral upper-limb arteriovenous fistula who underwent left internal thoracic artery grafting, Cuthbert and colleagues[24] found that 28% of patients had evidence of steal syndrome, and the authors recommended routine use of contralateral thoracic artery grafting. Others have found lower early rates of saphenous vein graft patency in patients on dialysis.[25] Additionally, a best-evidence review of cardiac surgery in dialysis-dependent patients found evidence that outcomes were better with off-pump CABG.[26] Finally, minimizing medication errors and omissions, along with providing comprehensive discharge instructions and high-level communication, has been shown to be beneficial in reducing readmissions in patients on dialysis.[22] Investigation into improving outcomes in patients with CKD/ESRD by including them in clinical trials may lead to valuable insights.

Two recent meta-analyses, each with 11 studies and more than 25,000 patients with CKD, examined outcomes for percutaneous coronary intervention and CABG. In a review of 26,441 patients, Cui and colleagues[27] found that early mortality and early stroke were less common with percutaneous coronary intervention, whereas long-term all-cause and cardiovascular mortality, repeat revascularization, and composite major adverse cardiac and cerebrovascular event rate favored CABG. Wang and colleagues,[28] in a review of 29,246 patients, found early and late outcomes similar to Cui and colleagues', but a subgroup analysis found that ESRD made no significant difference in the incidence of stroke and major adverse cardiac and cerebrovascular events.

The value of coronary revascularization has been subject to more scrutiny in renal transplant candidates. A recent meta-analysis of 8 studies and 945 patients showed that revascularization versus optimal medical therapy made no difference in all-cause mortality, cardiovascular mortality, or major cardiovascular events for patients who had received a renal transplant or were on the waitlist for one.[29] Although our study was not designed to identify the optimal medical or revascularization strategy in patients with CKD or ESRD, the indications for revascularization in these patients may continue to evolve.

In the postoperative phase, avoiding hyperglycemia,[30] monitoring novel renal biomarkers,[31] and using nephrology care bundles[32] as part of a comprehensive approach to reducing patients' risk of acute kidney injury have been shown to reduce morbidity and mortality after CABG. General principles of reducing readmission include promptly returning patients to their dry weight, medicine reconciliation, and early follow-up with nephrologists.[22] Another approach to reducing readmission rates is careful risk-stratification for patients with CKD by using a multidisciplinary heart team to identify potential causes of readmission and to address them promptly.[33]

To address the burden imposed by high rates of readmission after CABG procedures, prior studies have suggested a multi-pronged approach including patient education, telemonitoring, cardiac rehabilitation, and close follow-up as the foundation of care for these patients.[34] One study found that beyond these measures, perhaps one of the most important interventions is to identify specifically the cause of readmission and tailor the strategy accordingly to achieve the best possible outcomes.[4]

Study Limitations

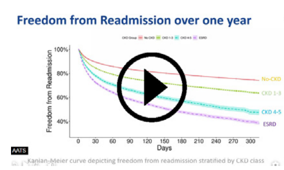
First, this study has the inherent limitations of all retrospective analyses of administrative databases. We attempted to ameliorate these limitations by using standardized practices and reproducible methods and using native variables in the NRD wherever possible. Second, the NRD itself has intrinsic limitations. These include the need for ICD-10–based derivations of patient comorbidities (which may underestimate CKD, especially at low stages[35]), lack of detailed admission data (eg, ejection fraction, admission medications, intensive care unit LOS, race/ethnicity), lack of information about preprocedural risk modification, and unreliable coding of certain pertinent patient data, such as acute kidney injury in patients at higher CKD stages. Additionally, for any given calendar year, the NRD tracks readmissions through only the end of that year, so we had to exclude patients from the analyses of 30- and 90-day readmission if their index admission occurred at less than 30 and 90 days, respectively, from the end of the year. The NRD is built from state databases, so patients readmitted in another state may not be correctly tracked in the NRD. Out-of-hospital deaths might not be reported in the NRD, so competing-risk analysis was not possible. Overall, however, the NRD is a robust, highly used database for estimating national rates of outcomes and readmissions. Third, because of the way dialysis is coded, it is not possible to determine whether a patient had dialysis dependence on admission or new-onset dialysis dependence during the index admission. Thus, we could not accurately assess the incidence of new-onset postoperative dialysis dependence. We determined the prevalence of ESRD by the relevant ICD-10 code.

CONCLUSIONS

Risk of mortality, readmission, and progression to dialysis after CABG is proportionally greater at more advanced CKD stages. A previously described regimen of close multidisciplinary follow-up and adequate cardiac rehabilitation, coupled with diligence on the part of the surgeon in the patient-selection process and proper patient education, may reduce costly readmissions and improve outcomes after CABG in patients with CKD.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/1945.



Conflict of Interest Statement

J.S.C. participates in clinical studies with and consults for Terumo Aortic, Medtronic, WL Gore & Associates, CytoSorbents, Edwards Lifesciences, and Abbott Laboratories, and receives royalties and grant support from Terumo Aortic. M.R.M. serves on the advisory board for Medtronic. S.C. has served on advisory boards for Edwards Lifesciences, La Jolla Pharmaceutical Company, Eagle Pharmaceuticals, and Baxter Pharmaceuticals. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: coronary artery bypass grafting, end-stage renal disease, kidney disease, national readmissions database, readmissions

TABLE E1. ICD-10 codes used for inclusion, exclusion, and grouping

Procedure	Description
Included procedures	
ICD-10-PCS 02100*	Bypass of coronary artery, 1 artery, open approach
ICD-10-PCS 02110*	Bypass of coronary artery, 2 arteries, open approach
ICD-10-PCS 02120*	Bypass of coronary artery, 3 arteries, open approach
ICD-10-PCS 02130*	Bypass of coronary artery, 4 or more arteries, open approach
Excluded procedures	
02QF*	Repair of aortic valve
02QG*	Repair of mitral valve
02QH*	Repair of pulmonary valve
02QJ*	Repair of tricuspid valve
02QW*	Repair of thoracic aorta, descending
02RF*	Replacement of aortic valve
02RG*	Replacement of mitral valve
02RX*	Replacement of thoracic aorta, ascending/arch
02RH*	Replacement of pulmonary valve
02RJ*	Replacement of tricuspid valve
02RW*	Replacement of thoracic aorta, descending
02H03*, 02H04*	Insertion in coronary artery, 1 artery, of device, percutaneous
02H13*, 02H14*	Insertion in coronary artery, 2 arteries, of device, percutaneous
02H23*, 02H24*	Insertion in coronary artery, 3 arteries, of device, percutaneous
02H33*, 02H34*	Insertion in coronary artery, 4 or more arteries, of device, percutaneous
02HW3*, 02HW4*	Insertion in thoracic aorta, descending, of device, percutaneous
02HX3*, 02HX4*	Insertion in thoracic aorta, ascending/arch, of device, percutaneous
02703*, 02704*	Dilation of coronary artery, 1 artery, percutaneous
Excluded diagnoses	
I25.42	Coronary artery dissection
I33.0	Acute and subacute infective endocarditis

ICD-10-PCS, International Classification of Diseases, 10th Revision, Procedural Classification. *Represents all combinations of codes beginning with that extension.

TABLE E2. Patient characteristics associated with operative mortality and 90-day readmission

	In-hospital mortality		90-d readmission	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Elixhauser >5	2.25 (1.97-2.58)	<.001	1.10 (1.06-1.13)	<.001
CKD group				
No CKD	reference	reference		
CKD 1-3	1.26 (1.14-1.39)	<.001	1.30 (1.25-1.35)	<.001
CKD 4-5	1.70 (1.42-2.02)	<.001	1.70 (1.56-1.84)	<.001
ESRD	2.72 (2.41-3.07)	<.001	2.61 (2.46-2.78)	<.001
Age ≥65 y	1.78 (1.65-1.93)	<.001	1.18 (1.15-1.22)	<.001
Medicaid or Self-pay	1.26 (1.11-1.42)	<.001	1.25 (1.20-1.31)	<.001
Lowest ZIP code income quartile	1.22 (1.12-1.32)	<.001	1.11 (1.08-1.15)	<.001
Female	1.73 (1.60-1.86)	<.001	1.41 (1.37-1.45)	<.001
Elective	0.64 (0.59-0.69)	<.001	0.83 (0.81-0.85)	<.001
Chronic heart failure	1.94 (1.78-2.12)	<.001	1.32 (1.28-1.35)	<.001
Arrhythmia	1.72 (1.60-1.85)	<.001	1.25 (1.22-1.29)	<.001
Valvular heart disease	0.97 (0.88-1.07)	.6	1.07 (1.04-1.11)	<.001
Pulmonary circulation disorder	1.40 (1.26-1.57)	<.001	1.18 (1.12-1.24)	<.001
Peripheral vascular disease	1.44 (1.33-1.57)	<.001	1.31 (1.27-1.35)	<.001
Hypertension	0.59 (0.54-0.65)	<.001	0.97 (0.93-1.01)	.2
Neurological disorder	3.82 (3.51-4.17)	<.001	1.51 (1.44-1.58)	<.001
Chronic pulmonary disease	0.99 (0.91-1.07)	.7	1.33 (1.30-1.37)	<.001
Diabetes	0.83 (0.77-0.89)	<.001	1.29 (1.26-1.33)	<.001
Hypothyroidism	0.80 (0.72-0.89)	<.001	1.05 (1.01-1.10)	.015
Peptic ulcer disease	0.93 (0.59-1.44)	.7	1.25 (1.08-1.45)	.003
Coagulopathy	1.75 (1.62-1.90)	<.001	1.01 (0.97-1.05)	.6
Obesity	0.93 (0.85-1.02)	.11	1.02 (1.00-1.05)	.090

OR, Odds ratio; *CI*, confidence interval; *CKD*, chronic kidney disease; *ESRD*, end-stage renal disease.