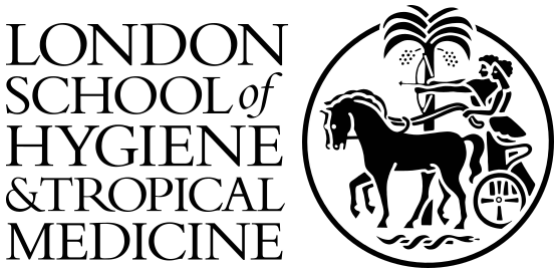

Left Main Revascularization with PCI or CABG in Patients with Chronic Kidney Disease: The EXCEL Trial

Running Title: Left Main Revascularization and Chronic Kidney Disease

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Word count: 4,520

Disclosures: Roxana Mehran: Institutional research grant support - Eli Lilly/Daiichi-Sankyo, Inc., Bristol-Myers Squibb, AstraZeneca, The Medicines Company, OrbusNeich, Bayer, CSL Behring, Abbott Laboratories, Watermark Research Partners, Novartis Pharmaceuticals, Medtronic, AUM Cardiovascular, Inc., Beth Israel Deaconess Medical Center; executive committee - Janssen Pharmaceuticals, Osprey Medical Inc.; data safety monitoring board - Watermark Research Partners; consulting - Medscape, The Medicines Company, Boston Scientific, Merck & Company, Cardiovascular Systems, Inc. (CSI); Sanofi USA, LLC, Shanghai BraccoSine Pharmaceutical Corp.; AstraZeneca; equity - Claret Medical Inc., Elixir Medical Corporation. Patrick W. Serruys: Consultant – Abbott, Biosensors, Medtronic, Micell Technologies, QualiMed, SINOMED, St. Jude Medical, Stentys, Svelte, Philips/Volcano, Xeltis. Joseph F. Sabik: Consultant - Medtronic, Edwards, and Sorin. Advisory board - Medtronic Cardiac Surgery. Charles A. Simonton: Employee - Abbott Vascular. David E. Kandzari: Consultant - Medtronic, Boston Scientific, Biotronik, Micell Technologies, Cardinal Health; institutional research/grant support - Medtronic, Boston Scientific, Biotronik, Micell Technologies, Medinol. Philippe Genereux: Speaker's fees - Edwards Lifescience, Medtronic, Tryton Medical Inc., Cardinal Health, and Cardiovascular Systems Inc., consulting fees - Boston Scientific, Cardiovascular Systems Inc., and Pi-Cardia; institutional research grant - Boston Scientific. Equity - SIG.NUM, SoundBite Medical Solutions Inc., Saranas, and Pi-Cardia. Stuart J. Pocock: Consultant - Abbott Vascular. A. Pieter Kappetein: Employee – Medtronic. Gregg W. Stone: Employer, Columbia University, receives royalties for sale of the MitraClip. The rest of the authors: None.

Twitter handle

@GreggWStone
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Short tweet (Max 150 characters)

Compared with CABG, PCI is associated with lower rates of adverse events at 30 days and similar outcomes at 3 years of follow-up in patients with left main disease and CKD.

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ABSTRACT

BACKGROUND: The optimal revascularization strategy for patients with left main coronary artery disease (LMCAD) and chronic kidney disease (CKD) remains unclear.

OBJECTIVES: We investigated the comparative effectiveness of percutaneous coronary intervention (PCI) versus coronary artery bypass graft (CABG) surgery in patients with LMCAD and low or intermediate anatomical complexity according to baseline renal function from the multicenter randomized EXCEL trial.

METHODS: CKD was defined as an estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2 using the CKD-EPI equation. Acute renal failure (ARF) was defined as a serum creatinine increase of ≥5.0 mg/dL from baseline or a new requirement for dialysis. The primary composite endpoint was the composite of death, myocardial infarction (MI), or stroke at 3-year follow-up.

RESULTS: CKD was present in 361 of 1,869 randomized patients (19.3%) in whom baseline eGFR was available. Patients with CKD had higher 3-year rates of the primary endpoint compared to those without CKD (20.8% vs. 13.5%; hazard ratio [HR]: 1.60; 95% confidence interval [CI]: 1.22-2.09; p=0.0005). ARF within 30 days occurred more commonly in patients with compared to those without CKD (5.0% vs. 0.8%, p<0.0001), and was strongly associated with the 3-year risk of death, stroke or MI (50.7% vs. 14.4%; HR: 4.59; 95% CI: 2.73-7.73; p<0.0001). ARF occurred less commonly after revascularization with PCI compared with CABG both in patients with CKD (2.3% vs. 7.7%; HR: 0.28; 95% CI: 0.09-0.87) and in those without CKD (0.3% vs. 1.3%; HR: 0.20; 95% CI: 0.04-0.90; $p_{interaction}$=0.71). There were no significant differences in the rates of the primary composite endpoint after PCI and CABG in patients with CKD (23.4% vs. 18.1%; HR: 1.25; 95% CI: 0.79-1.98) and without CKD (13.4% vs. 13.5%; HR: 0.97; 95% CI: 0.73-1.27; $p_{interaction}$=0.38).

CONCLUSIONS: Patients with CKD undergoing revascularization for LMCAD in the EXCEL trial had increased rates of ARF and reduced event-free survival. ARF occurred less frequently after PCI compared to CABG. Nonetheless, PCI and CABG resulted in non-significantly different rates of death, stroke or MI at 3 years in patients with and without CKD.

KEYWORDS: Left main; coronary artery disease; percutaneous coronary intervention; coronary artery bypass grafting; chronic kidney disease

CONDENSED ABSTRACT

The optimal revascularization strategy for patients with obstructive left main coronary artery disease (LMCAD) and chronic kidney disease (CKD) remains unclear. We investigated the comparative effectiveness of percutaneous coronary intervention (PCI) with everolimus-eluting stents versus coronary artery bypass graft (CABG) surgery in patients with LMCAD and CKD from the randomized EXCEL trial. At 3 years, there were no significant differences in the rates of death, myocardial infarction, or stroke between PCI and CABG in patients with (23.4% vs. 18.1%; HR: 1.25; 95% confidence interval [CI]: 0.79–1.98) or without CKD (13.4% vs. 13.5%; HR: 0.97; 95% CI: 0.73–1.27) ($p_{interaction}$=0.38).

ABBREVIATIONS AND ACRONYMS

ARF = acute renal failure

CABG = coronary artery bypass graft

CKD = chronic kidney disease

CrCl = creatinine clearance

EES = everolimus-eluting stents

eGFR = estimated glomerular filtration rate

LMCAD = left main coronary artery disease

MDRD = Modification of Diet in Renal Disease

PCI = percutaneous coronary intervention

Chronic kidney disease (CKD) is an increasingly prevalent condition and is strongly associated with increased cardiovascular morbidity and mortality (1). Renal dysfunction is associated with systemic inflammation, endothelial dysfunction, accelerated atherosclerosis, and enhanced thrombogenicity, which together heighten the risk for cardiovascular and cerebrovascular ischemic events (1-4). CKD is associated with a poor prognosis after coronary artery bypass graft surgery (CABG), due in part to the risk of acute renal failure (ARF) as well as associated comorbidities (2-4). However, the risk of ARF from contrast media, atheroemboli and other mechanisms is also increased in patients with CKD undergoing percutaneous coronary intervention (PCI) (5,6). These risks likely explain why patients with coronary artery disease (CAD) and CKD are less likely to undergo revascularization than those with normal renal function (2-4), despite observational studies suggesting a survival benefit after PCI and CABG in patients with multivessel disease and CKD (4). Few data comparing PCI and CABG in patients with CKD from prospective randomized trials are available to guide clinical decision-making in this high-risk group (7-11). We therefore examined the outcomes of patients with left main CAD (LMCAD) with and without CKD randomized to PCI with everolimus eluting-stents (EES) versus CABG in the Evaluation of XIENCE Versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularization (EXCEL) trial (12).

METHODS

Study design. The EXCEL trial design and principal results have been previously reported (12,13). In brief, EXCEL was an international, open-label, multicenter randomized trial that compared PCI using cobalt–chromium fluoropolymer-based EES (Xience; Abbott Vascular, Santa Clara, CA) versus CABG in patients with LMCAD. Inclusion criteria were LM diameter stenosis of ≥70%, as estimated visually, or stenosis of 50% to <70% if hemodynamically significant by non-invasive or invasive testing, plus low or intermediate anatomical complexity of CAD as defined by a site-determined Synergy between PCI with Taxus and Cardiac Surgery (SYNTAX) score of ≤32.

Consensus among the members of the heart team for revascularization with either PCI or CABG was required. Clinical follow-up was performed at 1 month, 6 months, and 1 year and then annually through 5 years. At the time of the current analysis all patients have completed 3 years of follow-up. The investigation was approved by the ethics committee or institutional review board at each center, and all patients signed informed consent.

The primary endpoint was the composite of death from any cause, stroke, or myocardial infarction (MI) at 3 years. Major powered secondary endpoints included this composite rate at 30 days, and death, stroke, MI, or ischemia-driven revascularization at 3 years. Additional secondary endpoints included the components of the primary endpoint, as well as revascularization, stent thrombosis, symptomatic graft occlusion, bleeding complications, and a pre-specified composite of major adverse events occurring within 30 days. These endpoint definitions are reported elsewhere (12). Study monitors collected source documents of all primary and secondary endpoint events for adjudication by an independent clinical events committee. The extent and complexity of CAD and the SYNTAX score were also assessed by an independent angiographic core laboratory.

The present study is a pre-specified subgroup analysis from the EXCEL trial comparing PCI and CABG in patients with and without CKD. CKD was defined as an estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2 (corresponding to CKD stage 3A, 3B, 4, or 5), using the CKD-EPI equation as per the National Kidney Foundation-Kidney Disease Outcomes Quality Initiative guidelines (Supplemental Appendix Table 1) (14,15). This equation is preferentially endorsed by consensus guidelines as superior to other equations to discriminate between patients with versus without renal dysfunction and to predict adverse events in patients with CKD (16,17). ARF was defined in the protocol as a serum creatinine increase by ≥5.0 mg/dL from baseline or new requirement for dialysis (including hemodialysis, continuous veno-venous hemofiltration or peritoneal dialysis).

Statistical analysis. All analyses were performed in the intention-to-treat population, which included all patients according to the group to which they were randomly assigned, regardless of the treatment received. The median duration of follow-up in the current analysis was 3 years (interquartile range 3 to 3 years). Categorical variables were compared with the use of the χ^2 test or Fisher exact test. Continuous variables were compared with the use of the Student *t* test or the Wilcoxon rank-sum test for non-normally distributed data. Event rates were based on Kaplan–Meier estimates in time-to-first-event analyses and were compared with the log-rank test. The association between baseline renal function (as a continuous variable) and the 3-year hazard of adverse events was also evaluated using a smoothing spline function. Hazard ratios (HR) with 95% confidence intervals (CI) were generated with Cox regression models with treatment as the main effect. The statistical significance of differences in the treatment effect of PCI versus CABG in patients with and without CKD was assessed in Cox regression models for the full trial population, including main effect terms (eg, CKD and assigned treatment) and interaction terms (eg, CKD × assigned treatment) for each outcome of interest. Primary analyses were performed using the CKD-EPI formula to define baseline CKD (14). For sensitivity analysis, we assessed the comparative effectiveness of PCI versus CABG implementing alternative equations to estimate baseline renal function, specifically the Modification of Diet in Renal Disease (MDRD) equation (14) and the Cockcroft-Gault equation (18). The renal function equation definitions are shown in Supplemental Appendix Table 1. A 2-sided p value of ≤0.05 was considered to indicate statistical significance. All statistical analyses were performed with the use of SAS software, version 9.4 (SAS Institute, Cary, North Carolina).

RESULTS

Baseline renal function was evaluable in 1,869 of 1,905 randomized patients (98.1%), among whom CKD was present in 361 (19.3%), 300 (16.1%), and 308 (16.5%) using the CKD-EPI, MDRD, and Cockcroft-Gault equations, respectively. The mean estimated eGFR using the CKD-

EPI, MDRD, and Cockcroft-Gault equations was 77.2±19.1 mL/min/1.73 m^2, 81.5±22.8 mL/min/1.73 m^2, and 89.5±32.4 mL/min in all patients, and 48.6±9.9 mL/min/1.73 m^2, 49.2±9.7 mL/min/1.73 m^2, and 47.8±9.6 mL/min in patients with CKD, respectively. The distribution of baseline eGFR using the CKD-EPI equation is illustrated in Figure 1. Only 3/361 enrolled patients with CKD at baseline were on dialysis (0.8%).

Baseline characteristics in patients with and without CKD estimated with the CKD-EPI equation are reported in Table 1. Patients with CKD were older, were more commonly female and had more comorbidities. Patients with CKD were also more likely to have a history of prior MI, atrial fibrillation, valvular heart disease, and lower left ventricular ejection fraction. Baseline angiographic characteristics and procedural characteristics with PCI or CABG are reported in Table 2. There were no significant differences in site-reported or core laboratory-assessed SYNTAX scores between patients with and without CKD; however, patients with CKD were more likely to have diffuse or small vessel disease. There were no significant differences in the number of non-left main stented or bypassed vessels in patients with and without CKD (Table 2). Medication use at discharge and through 3 years in patients with and without CKD were similar, except for greater use of chronic oral anticoagulants in those with CKD (Supplemental Appendix Table 2).

Effect of CKD on outcomes. Patients with compared to those without CKD had higher rates of 30-day composite major adverse events, including more frequent blood transfusions, major arrhythmias, infections, sternal would dehiscence, and unplanned surgical and radiologic procedures (Supplemental Appendix Table 3). In addition, the rate of ARF was ~6 times greater in patients with CKD compared to those without (5.0% vs. 0.8%, p<0.0001). The 3-year primary composite endpoint of death, stroke, or MI was increased in patients with compared to those without CKD (Figure 2; 20.8% vs. 13.5%; hazard ratio: 1.60; 95% CI: 1.22-2.09; p=0.0005), driven by greater cardiac and non-cardiac mortality (Table 3). The rates of adverse outcomes incrementally increased as renal function worsened from eGFR >60 mL/min/1.73 m^2 (no CKD) to eGFR 45 to 60 mL/min/1.73 m^2 (Stage 3A CKD) to eGFR<45 mL/min/1.73 m^2 (Stage 3B, 4, or 5 CKD)

(Supplemental Appendix Table 4). When modeled as a continuous variable, progressively lower eGFR was associated with a steadily greater 3-year risk of death, stroke, or MI (HR per 10 mL/min/1.73 m^2 decrease: 1.09; 95% CI: 1.03-1.15; p=0.004) and all-cause death (HR per 10 mL/min/1.73 m^2 decrease: 1.23; 95% CI: 1.14-1.34; p<0.0001) (Figure 3A and 3B). Results were consistent using the MDRD and the Cockcroft-Gault equations (Supplemental Appendix Tables 5 and 6).

PCI versus CABG in patients with and without CKD. PCI was associated with lower 30-day rates of major adverse events compared with CABG, in patients with and without CKD (Table 4). PCI was also associated with shorter in-hospital stay compared with CABG both in patients with CKD (6.7±7.0 vs. 16.1±15.2; p<0.0001) and without CKD (5.2±4.7 vs. 11.9±7.4; p<0.0001). At 30 days, PCI compared with CABG resulted in lower rates of the composite endpoint of death, MI, or stroke both in patients with CKD (6.2% vs. 9.3%, HR: 0.68; 95% CI: 0.32-1.45) and without CKD (4.5% vs. 7.4%, HR: 0.61; 95% CI: 0.40-0.93) ($p_{interaction}$=0.80). At 3 years (Figure 4), there were no significant differences in the rates of the primary composite endpoint of death, MI, or stroke after PCI versus CABG, an effect that was consistent in patients with and without CKD ($p_{interaction}$=0.36) (Table 5). The 3-year relative rates of the components of the primary endpoint, as well as revascularization and bleeding after PCI versus CABG were also consistent in patients with and without CKD (Table 5). CABG was associated with less ischemia-driven revascularization during follow-up, the risk of which was consistent across varying levels of baseline renal function (Supplemental Appendix Table 7). In the CKD group, 3-year mortality was increased after PCI compared with CABG, due to greater non-cardiac deaths, specifically due to sepsis (5.4% vs. 1.1%; p=0.02), which occurred more than 30 days post procedure. There was no significant difference in cardiac mortality after PCI vs. CABG either in patients with or without CKD. The comparative effectiveness of PCI versus CABG on the risk of death, MI, or stroke at 30 days and 3 years was consistent across varying definitions of CKD (Figure 5).

ARF and outcomes after LM revascularization. Baseline clinical and procedural characteristics which were associated with the development of ARF within 30 days are reported in Supplemental Appendix Table 8. Compared with CABG, PCI was associated with significantly lower rates of ARF at 30 days in both patients with CKD (2.3% vs. 7.6%; HR: 0.28; 95% CI: 0.09-0.87) and in those without CKD (0.3% vs. 1.3%; HR: 0.20; 95% CI: 0.04-0.90; $p_{interaction}$=0.71) (Table 6). Dialysis was also required more frequently after CABG compared with PCI, regardless of baseline CKD status ($p_{interaction}$=0.87). Outcomes at 3 years in patients with versus without ARF within 30 days are reported in Supplemental Appendix Table 9. The occurrence of ARF was strongly associated with increased 3-year risk of death, stroke or MI at 3 years (50.7% vs. 14.4%; HR: 4.59; 95% CI: 2.73-7.73; p<0.0001).

DISCUSSION

The Central Illustration demonstrates the major findings of the present pre-specified analysis from the EXCEL trial, in which we explored the relative effects of PCI with EES versus CABG in patients with LMCAD and low or intermediate SYNTAX scores according to baseline renal function. Progressively worse renal impairment in patients undergoing LM revascularization was associated with steadily increasing rates of cardiovascular and hemorrhagic adverse events and mortality during 3 years of follow-up. Compared with CABG, PCI was associated with lower rates of ARF, including dialysis, and 30-day major adverse events in both patients with and without CKD. The occurrence of ARF at 30 days was strongly associated with increased risk of adverse events and mortality over 3 years of follow-up. At 3 years, however, there were no significant differences in the rates of death, MI, or stroke between PCI-treated and CABG-treated patients, regardless of baseline CKD. Despite the fact that definite stent thrombosis occurred less frequently than symptomatic graft failure, ischemia-driven revascularization rates at 3 years were lower after CABG compared to PCI, an effect that was consistent in patients with preserved or reduced renal

function. Finally, the impact of CKD, and the comparative outcomes of PCI versus CABG in patients with and without CKD were consistent irrespective of definition of renal dysfunction.

Evidence from prior randomized trials to inform revascularization decisions in patients with CKD is scarce, especially in LMCAD. Among diabetic patients with CKD and non-LM multivessel disease enrolled in the Future Revascularization Evaluation in Patients with Diabetes Mellitus: Optimal Management of Multivessel Disease (FREEDOM) trial, CABG compared with PCI with paclitaxel-eluting stents resulted in a 27% relative risk reduction in major adverse cardiovascular and cerebrovascular events (MACCE) at a median follow-up of 3.8 years (7). Among CKD patients with non-LM multivessel disease enrolled in the New York State outcomes registries, PCI with EES was associated with lower rates of MACCE at 30 days than CABG, but higher rates of MI and repeat revascularization at 4 years, with similar rates of death (19). In a pooled analysis from the Bypass Surgery Versus Angioplasty Using Sirolimus-Eluting Stent in Patients With Left Main Coronary Artery Disease (PRECOMBAT) and SYNTAX trials, PCI with first-generation paclitaxel-eluting and sirolimus-eluting stents was associated with comparable 5-year rates of MACCE and death compared with CABG in patients with LMCAD with and without CKD, without significant interaction (20).

The present large-scale study in which contemporary DES and revascularization techniques were used confirms and extends these prior findings to patients with LMCAD. Patients with CKD constituted ~25% of the EXCEL trial population, in whom the mean eGFR was 48.5±9.9 mL/min/1.73 m^2, representing moderately severe CKD. PCI with EES in patients with LMCAD reduced 30-day periprocedural adverse events and the 30-day composite rate of death, stroke, or MI consistently in both CKD and non-CKD cohorts. Specifically, PCI resulted in reduced bleeding, need for transfusions, arrhythmias, and less ARF (including the need for dialysis) compared with CABG in patients with CKD, adverse events which have been associated with long-term mortality (21-27). In this regard, ARF in the EXCEL trial was defined as an increase in serum creatinine ≥5 mg/dL or a new requirement for dialysis, corresponding to acute kidney injury of stage III or greater

in the most recent Kidney Disease: Improving Global Outcomes (KDIGO) classification (28). ARF as so defined was strongly associated with worse outcomes over 3 years of follow-up. The reduced rate of ARF after PCI compared with CABG in both the CKD and non-CKD cohorts is one factor that should considered when deciding between revascularization strategies to avoid further declines in renal function in patients with CKD. However, the composite 3-year primary endpoint rate of death, MI, or stroke was similar after PCI and CABG, a finding that was consistent in patients with and without CKD. The lower rates of MI and revascularization during the follow-up period after CABG compared to PCI as initially described in EXCEL (7) may have offset the deleterious effects of ARF and surgical complications in the CKD cohort.

Renal dysfunction has been associated with late DES failure (29-31). Nonetheless, the 3-year rates of definite EES thrombosis were lower than the rates of symptomatic graft occlusion in patients with and without CKD, and ischemia-driven revascularization after EES within 3 years was required in only 10.9% of patients with CKD compared to 13.0% of patients without CKD. These observations demonstrate that the anti-thrombotic and anti-restenotic properties of EES are preserved in higher-risk CKD patients and lesions (32,33). It thus follows that improved chronic medical therapy regimens are required to slow progressive atherosclerosis if the long-term prognosis of high-risk CKD patients is to be improved after PCI (and CABG). Toward this end insights may be gained from the ongoing International Study of Comparative Health Effectiveness With Medical and Invasive Approaches–Chronic Kidney Disease (ISCHEMIA-CKD) trial [NCT01985360] in which patients with stable ischemic heart disease and advanced CKD (eGFR<30 mL/min/1.73 m^2 or dialysis) are being assigned to an invasive revascularization strategy versus initial medical management.

Limitations. First, although the present study was pre-specified, the CKD and non-CKD subgroups were not individually powered to draw definitive conclusions as to whether PCI or CABG should be favored. Randomization was not stratified by renal function, and the role of unmeasured confounders cannot be excluded. Our findings should thus be considered hypothesis-

generating. Second, while some patients with severe CKD were included, the majority had moderate renal impairment. Therefore, our findings cannot be extrapolated to a severe CKD and end-stage renal disease population. Third, EXCEL enrolled patients with LMCAD and site-assessed low and intermediate anatomical complexity. Our findings therefore do not apply to patients with CAD and extreme anatomic complexity. Nonetheless, the mean core laboratory-assessed SYNTAX score in the EXCEL trial of 26.5 was roughly comparable to that from the FREEDOM trial (mean 26.2) and the SYNTAX trial (mean 28.8), implying that the present results may inform outcomes in patients with more extensive CAD. Finally, follow-up in EXCEL is complete through only 3 years. Longer-term follow-up (currently planned for 5 years) is required to determine whether additional late differences between PCI and CABG emerge.

Conclusions. In patients with LMCAD and site-assessed low or intermediate SYNTAX scores undergoing revascularization, the presence of CKD was associated with a substantially greater risk of periprocedural adverse events and mortality during 3-year follow-up. Although PCI with EES was associated with significantly lower 30-day rates of ARF and major adverse events compared with CABG, there were no significant differences between the revascularization modalities for the primary composite endpoint or components of death, MI, or stroke at 3 years, with no interaction according to baseline CKD status. Both PCI and CABG are thus acceptable revascularization approaches in selected high-risk patients with LMCAD and CKD. Individual patient comorbidities, the likelihood to safely obtain complete revascularization, and patient preferences as to the early benefits of PCI versus the late benefits of CABG should thus be factored into the heart team decision-making process in high-risk patients with LMCAD and CKD.

CLINICAL PERSPECTIVES

- **Competency in Medical Knowledge (1):** Patients with CKD and LMCAD undergoing revascularization are at substantially greater risk for ARF, periprocedural adverse events, and mortality over 3 years of follow-up.
- **Competency in Medical Knowledge (2):** PCI with EES in patients with CKD and LMCAD with site-assessed low or intermediate anatomical complexity is associated with lower rates of 30-day adverse events including ARF, major bleeding, and arrhythmias compared with CABG. Over 3 years of follow-up, PCI and CABG resulted in comparable rates of death, MI, or stroke, irrespective of baseline renal function.
- **Competency in Patient Care:** Both PCI and CABG are acceptable revascularization strategies for high-risk patients with CKD and LMCAD. Individual patient comorbidities, patient preferences, and the early benefits of PCI versus the late benefits of CABG should be taken into account by the heart team when deciding between the two revascularization strategies.
- **Translational Outlook:** Improved chronic medical therapy regimens are required to slow progressive atherosclerosis if the long-term prognosis of high-risk CKD patients is to be improved after PCI and CABG.

REFERENCES

1. Go AS, Chertow GM, Fan D, McCulloch CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. The New England journal of medicine 2004;351:1296-305.
2. Mathew RO, Bangalore S, Lavelle MP et al. Diagnosis and management of atherosclerotic cardiovascular disease in chronic kidney disease: a review. Kidney Int 2017;91:797-807.
3. Bangalore S. Diagnostic, Therapeutic, and Clinical Trial Conundrum of Patients With Chronic Kidney Disease. JACC Cardiovasc Interv 2016;9:2110-2112.
4. Volodarskiy A, Kumar S, Amin S, Bangalore S. Optimal Treatment Strategies in Patients with Chronic Kidney Disease and Coronary Artery Disease. Am J Med 2016;129:1288-1298.
5. Mehran R, Aymong ED, Nikolsky E et al. A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: development and initial validation. J Am Coll Cardiol 2004;44:1393-9.
6. Giustino G, Baber U, Mastoris I et al. One-year results of the ICON (Ionic versus non-ionic Contrast to Obviate worsening Nephropathy after angioplasty in chronic renal failure patients) Study. Catheter Cardiovasc Interv 2016;87:703-9.
7. Baber U, Farkouh ME, Arbel Y et al. Comparative efficacy of coronary artery bypass surgery vs. percutaneous coronary intervention in patients with diabetes and multivessel coronary artery disease with or without chronic kidney disease. Eur Heart J 2016;37:3440-3447.
8. Cavalcante R, Sotomi Y, Lee CW et al. Outcomes After Percutaneous Coronary Intervention or Bypass Surgery in Patients With Unprotected Left Main Disease. J Am Coll Cardiol 2016;68:999-1009.
9. Piccolo R, Giustino G, Mehran R, Windecker S. Stable coronary artery disease: revascularisation and invasive strategies. Lancet 2015;386:702-13.

10. Giustino G, Mehran R. PCI and CABG surgery in 2014: CABG surgery versus PCI in CAD--surgery strikes again! Nat Rev Cardiol 2015;12:75-7.
11. Milojevic M, Head SJ, Mack MJ et al. The impact of chronic kidney disease on outcomes following percutaneous coronary interventions versus coronary artery bypass grafting in patients with complex coronary artery disease: 5-year follow-up of the SYNTAX trial. EuroIntervention 2017.
12. Stone GW, Sabik JF, Serruys PW et al. Everolimus-Eluting Stents or Bypass Surgery for Left Main Coronary Artery Disease. The New England journal of medicine 2016;375:2223-2235.
13. Kappetein AP, Serruys PW, Sabik JF et al. Design and rationale for a randomised comparison of everolimus-eluting stents and coronary artery bypass graft surgery in selected patients with left main coronary artery disease: the EXCEL trial. EuroIntervention 2016;12:861-72.
14. Levey AS, Stevens LA, Schmid CH et al. A new equation to estimate glomerular filtration rate. Ann Intern Med 2009;150:604-12.
15. Stevens PE, Levin A, Kidney Disease: Improving Global Outcomes Chronic Kidney Disease Guideline Development Work Group M. Evaluation and management of chronic kidney disease: synopsis of the kidney disease: improving global outcomes 2012 clinical practice guideline. Ann Intern Med 2013;158:825-30.
16. Parsh J, Seth M, Aronow H et al. Choice of Estimated Glomerular Filtration Rate Equation Impacts Drug-Dosing Recommendations and Risk Stratification in Patients With Chronic Kidney Disease Undergoing Percutaneous Coronary Interventions. Journal of the American College of Cardiology 2015;65:2714-23.
17. Levey AS, Stevens LA. Estimating GFR using the CKD Epidemiology Collaboration (CKD-EPI) creatinine equation: more accurate GFR estimates, lower CKD prevalence estimates, and better risk predictions. Am J Kidney Dis 2010;55:622-7.

18. Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. Nephron 1976;16:31-41.
19. Bangalore S, Guo Y, Samadashvili Z, Blecker S, Xu J, Hannan EL. Revascularization in Patients With Multivessel Coronary Artery Disease and Chronic Kidney Disease: Everolimus-Eluting Stents Versus Coronary Artery Bypass Graft Surgery. J Am Coll Cardiol 2015;66:1209-1220.
20. Cavalcante R, Sotomi Y, Lee CW et al. Outcomes After Percutaneous Coronary Intervention or Bypass Surgery in Patients With Unprotected Left Main Disease. J Am Coll Cardiol 2016;68:999-1009.
21. Mehran R, Pocock SJ, Nikolsky E et al. A risk score to predict bleeding in patients with acute coronary syndromes. J Am Coll Cardiol 2010;55:2556-66.
22. Filardo G, Hamilton C, Hebeler RF, Jr., Hamman B, Grayburn P. New-onset postoperative atrial fibrillation after isolated coronary artery bypass graft surgery and long-term survival. Circ Cardiovasc Qual Outcomes 2009;2:164-9.
23. Warren J, Mehran R, Baber U et al. Incidence and impact of acute kidney injury in patients with acute coronary syndromes treated with coronary artery bypass grafting: Insights from the Harmonizing Outcomes With Revascularization and Stents in Acute Myocardial Infarction (HORIZONS-AMI) and Acute Catheterization and Urgent Intervention Triage Strategy (ACUITY) trials. Am Heart J 2016;171:40-7.
24. Giacoppo D, Madhavan MV, Baber U et al. Impact of Contrast-Induced Acute Kidney Injury After Percutaneous Coronary Intervention on Short- and Long-Term Outcomes: Pooled Analysis From the HORIZONS-AMI and ACUITY Trials. Circ Cardiovasc Interv 2015;8:e002475.
25. Genereux P, Giustino G, Witzenbichler B et al. Incidence, Predictors, and Impact of Post-Discharge Bleeding After Percutaneous Coronary Intervention. J Am Coll Cardiol 2015;66:1036-45.

26. Baber U, Dangas G, Chandrasekhar J et al. Time-Dependent Associations Between Actionable Bleeding, Coronary Thrombotic Events, and Mortality Following Percutaneous Coronary Intervention: Results From the PARIS Registry. JACC Cardiovasc Interv 2016;9:1349-57.
27. Baber U, Mehran R, Giustino G et al. Coronary Thrombosis and Major Bleeding After PCI With Drug-Eluting Stents: Risk Scores From PARIS. J Am Coll Cardiol 2016;67:2224-34.
28. Section 2: AKI Definition. Kidney Int Suppl (2011) 2012;2:19-36.
29. Lee JM, Kang J, Lee E et al. Chronic Kidney Disease in the Second-Generation Drug-Eluting Stent Era: Pooled Analysis of the Korean Multicenter Drug-Eluting Stent Registry. JACC Cardiovasc Interv 2016;9:2097-2109.
30. Lu R, Tang F, Zhang Y et al. Comparison of Drug-Eluting and Bare Metal Stents in Patients With Chronic Kidney Disease: An Updated Systematic Review and Meta-Analysis. J Am Heart Assoc 2016;5.
31. Baber U, Giustino G, Sartori S et al. Effect of Chronic Kidney Disease in Women Undergoing Percutaneous Coronary Intervention With Drug-Eluting Stents: A Patient-Level Pooled Analysis of Randomized Controlled Trials. JACC Cardiovasc Interv 2016;9:28-38.
32. Chieffo A, Tanaka A, Giustino G et al. The DELTA 2 Registry: A Multicenter Registry Evaluating Percutaneous Coronary Intervention With New-Generation Drug-Eluting Stents in Patients With Obstructive Left Main Coronary Artery Disease. JACC Cardiovasc Interv 2017;10:2401-2410.
33. Giustino G, Baber U, Aquino M et al. Safety and Efficacy of New-Generation Drug-Eluting Stents in Women Undergoing Complex Percutaneous Coronary Artery Revascularization: From the WIN-DES Collaborative Patient-Level Pooled Analysis. JACC Cardiovasc Interv 2016;9:674-84.

FIGURE LEGENDS

FIGURE 1. Distribution of the Estimated Glomerular Filtration Rate in the EXCEL Trial Population Using The CKD-EPI Equation.

The left y-axis refers to the histogram of the number of patients with estimated glomerular filtration rate (eGFR) per 5 mL/min/1.73 m^2 increments. The right y-axis refers to the cumulative frequency distribution curve of eGFR values. The median [25%, 75%] eGFR was 79.2 [64.0, 91.3] mL/min/1.73 m^2 and the mean ± SD eGFR was 77.2±19.1 mL/min/1.73 m^2 (range 6.5–139.2 mL/min/1.73 m^2).

FIGURE 2. Three-Year Outcomes in Patients With Versus Without Chronic Kidney Disease.

Kaplan-Meier time-to-first event curves for death, myocardial infarction, or stroke during 3 years of follow-up in patients with and without chronic kidney disease (CKD). CI = confidence interval; GFR = glomerular filtration rate; HR = hazard ratio.

FIGURE 3. Risk of Adverse Events According to Baseline Renal Function.

Smooth hazard function for the risk of (A) death, myocardial infarction, or stroke, and (B) death at 3 years according to baseline renal function estimated with the CKD-EPI equation. CABG = coronary artery bypass grafting; CI = confidence interval; eGFR = estimated glomerular filtration rate; PCI = percutaneous coronary intervention.

FIGURE 4. Three-Year Outcomes in with PCI Versus CABG in Patients With or Without Chronic Kidney Disease.

Kaplan-Meier time-to-first event curves for death, myocardial infarction, or stroke during 3 years of follow-up according to randomized treatment with percutaneous coronary intervention (PCI) versus coronary artery bypass grafting (CABG) in patients with and without CKD. CI = confidence interval; GFR = glomerular filtration rate; HR = hazard ratio.

FIGURE 5. Thirty-Day and Three-Year Outcomes for Percutaneous Coronary Intervention Versus Coronary Artery Bypass Grafting Using Alternative Chronic Kidney Disease Equations.

CABG = coronary artery bypass grafting; CKD = chronic kidney disease; CKD-EPI = CKD Epidemiology Collaboration; CrCl = creatinine clearance; MDRD = Modification of Diet in Renal Disease; MI = myocardial infarction; PCI = percutaneous coronary intervention.

CENTRAL ILLUSTRATION. Risk and Benefits of Percutaneous Coronary Intervention Versus Coronary Artery Bypass Graft Surgery in Patients With Chronic Kidney Disease and Left Main Coronary Artery Disease With Site-Assessed Low or Intermediate SYNTAX Scores.

ARF = Acute Renal Failure; CABG = coronary artery bypass grafting; MI = myocardial infarction; PCI = percutaneous coronary intervention.

TABLE 1. Baseline Characteristics.

	Chronic Kidney Disease (n = 361)	No Chronic Kidney Disease (n = 1508)	p-value
Age, years	72.7 ± 7.8	64.3 ± 9.2	<0.0001
Male sex	239/361 (66.2%)	1200/1508 (79.6%)	<0.0001
Medical history			
Hypertension	306/361 (84.8%)	1073/1508 (71.2%)	<0.0001
Hyperlipidemia	266/360 (73.9%)	1038/1506 (68.9%)	<0.0001
Current smoker	44/359 (12.3%)	365/1497 (24.4%)	<0.0001
Prior stroke or transient ischemic attack	37/361 (10.2%)	80/1507 (5.3%)	0.0005
Congestive heart failure	43/361 (11.9%)	79/1503 (5.3%)	<0.0001
Diabetes mellitus	146/361 (40.4%)	403/1508 (26.7%)	<0.0001
Insulin-treated	46/361 (12.7%)	101/1508 (6.7%)	
Peripheral artery disease	48/359 (13.4%)	131/1503 (8.7%)	0.007
Chronic obstructive pulmonary disease	29/361 (8.0%)	115/1505 (7.6%)	0.80
Anemia	61/358 (17.0%)	121/1505 (8.0%)	<0.0001
Carotid artery disease	45/359 (12.5%)	109/1502 (7.3%)	0.001
On dialysis	3/361 (0.8%)	-	-
Cardiac history			
Prior percutaneous coronary intervention	70/360 (19.4%)	249/1507 (16.5%)	0.19
Prior myocardial infarction	77/357 (21.6%)	246/1497 (16.4%)	0.02
Atrial fibrillation	29/361 (8.0%)	42/1508 (2.8%)	<0.0001
Any baseline mitral regurgitation*	115/327 (35.2%)	400/1405 (28.5%)	0.02
Any baseline aortic regurgitation*	47/325 (14.5%)	143/1401 (10.2%)	0.03
Any baseline tricuspid regurgitation*	94/323 (29.1%)	355/1392 (25.5%)	0.18
Left ventricular ejection fraction, %	55.5 ± 10.6	57.5 ± 8.9	0.002
Clinical presentation			
Stable angina	189/360 (52.5%)	799/1502 (53.2%)	0.81
Unstable angina	87/360 (24.2%)	370/1502 (24.6%)	0.85
Non–STEMI†	43/357 (12.0%)	199/1498 (13.3%)	0.52
STEMI†	5/357 (1.4%)	22/1498 (1.5%)	0.92
Laboratory measures			
HbA1c, %	6.4 ± 1.3	6.2 ± 1.2	<0.0001
White blood cell count, $\times 10^9$/L	7.8 ± 2.1	7.8 ± 2.1	0.81
Hemoglobin, g/dL	12.7 ± 1.7	13.8 ± 1.5	<0.0001
Platelet count, $\times 10^9$/L	231.6 ± 71.5	226.8 ± 62.4	0.47
Brain natriuretic peptide, mg/L	450.8 ± 981.9	202.2 ± 453.5	<0.0001
High-sensitivity C-reactive protein, mg/L	9.1 ± 15.2	6.3 ± 12.6	0.001
Serum creatinine, mg/dL	1.4 ± 0.7	0.9 ± 0.2	<0.0001

Values are n/N (%) or mean ± standard deviation, as appropriate. *All were moderate or less; severe valve disease was an exclusion criterion; †within 7 days before randomization. STEMI = ST-segment elevation myocardial infarction.

TABLE 2. Angiographic and Procedural Characteristics in Patients With Versus Without CKD.

	Chronic Kidney Disease (n = 361)	No Chronic Kidney Disease (n = 1508)	p-value
Baseline angiographic characteristics			
SYNTAX score, site-reported	21.0 ± 6.0	20.4 ± 6.2	0.11
Low complexity (<23)	211/361 (58.4%)	917/1506 (60.9%)	
Intermediate complexity (23-32)	150/361 (41.6%)	589/1506 (39.1%)	
SYNTAX score, core laboratory assessed	26.5 ± 8.7	26.5 ± 9.4	0.63
Low complexity (<23)	111/348 (31.9%)	534/1457 (36.7%)	
Intermediate complexity (23-32)	157/348 (45.1%)	568/1457 (39.0%)	
High complexity (>32)	80/348 (23.0%)	355/1457 (24.4%)	
Left main diameter stenosis, %	75.7 ± 12.4	75.3 ± 12.0	0.60
Bifurcation or trifurcation disease of the distal left main segment	275/352 (78.1%)	1212/1491 (81.3%)	0.18
Number of non-left main diseased vessels			
0	49/352 (13.9%)	276/1491 (18.5%)	0.04
1	117/352 (33.2%)	455/1491 (30.5%)	0.32
2	122/352 (34.7%)	491/1491 (32.9%)	0.54
3	64/352 (18.2%)	269/1491 (18.0%)	0.95
Diffuse or small vessel disease	36/356 (10.1%)	76/1482 (5.1%)	0.0004
PCI characteristics			
Non-left main lesions stented per patient			
Left anterior descending artery	57/172 (33.1%)	207/750 (27.6%)	0.15
Left circumflex artery	31/172 (18.0%)	122/750 (16.3%)	0.58
Right coronary artery	41/172 (23.8%)	203/750 (27.1%)	0.39
Number of any stented lesions per patient	2.0 ± 1.1	1.9 ± 1.1	0.34
Number of any stented vessels per patient	1.7 ± 0.8	1.7 ± 0.8	0.55
Number of stents implanted per patient	2.6 ± 1.5	2.4 ± 1.5	0.09
Total stent length, per patient	50.9 ± 35.6	48.8 ± 35.8	0.27
Intravascular imaging used	133/172 (77.3%)	579/750 (77.2%)	0.97
Fractional flow reserve used	13/171 (7.6%)	70/750 (9.3%)	0.48
Time in the catheterization laboratory, min	112.6 ± 53.1	111.0 ± 52.5	0.81
CABG characteristics			
Coronary segments of distal anastomosis (CASS)			
Left anterior descending artery	174/176 (98.9%)	718/727 (98.8%)	1.00
Left circumflex artery	154/176 (87.5%)	644/727 (88.6%)	0.69
Right coronary artery	73/176 (41.5%)	268/727 (36.9%)	0.26
Number of vessels bypassed per patient	2.3 ± 0.6	2.2 ± 0.5	0.41
Number of conduits per patient	2.6 ± 0.8	2.6 ± 0.8	0.16
Number of arterial conduits per patient	1.3 ± 0.6	1.4 ± 0.6	0.31
Number of venous conduits per patient	1.3 ± 0.9	1.2 ± 1.0	0.10
Bypass duration, min	77.2 ± 33.1	85.3 ± 48.1	0.17
Time in the operating room, min	291.0 ± 76.6	282.9 ± 75.0	0.11

Values are n/N (%) or mean ± standard deviation, as appropriate. CASS = Coronary Artery Surgery Study.

TABLE 3. Three-Year Outcomes in Patients With Versus Without Chronic Kidney Disease

	Chronic Kidney Disease (n = 361)	No Chronic Kidney Disease (n = 1508)	Hazard Ratio (95% Confidence Interval)	p-value
Death, stroke, or myocardial infarction	20.8% (73)	13.5% (200)	1.60 (1.22-2.09)	0.0005
Death	12.9% (45)	5.4% (80)	2.48 (1.72-3.57)	<0.0001
Cardiac death	7.3% (25)	3.3% (48)	2.27 (1.40-3.69)	0.0006
Non-cardiac death	6.0% (20)	2.2% (32)	2.78 (1.59-4.86)	0.0002
Stroke	3.6% (12)	2.5% (36)	1.46 (0.76-2.80)	0.26
Myocardial infarction	9.0% (31)	8.0% (118)	1.13 (0.76-1.68)	0.54
Death, stroke, myocardial infarction, or ischemia-driven revascularization	24.2% (85)	19.9% (296)	1.25 (0.98-1.59)	0.07
Ischemia-driven revascularization	8.6% (29)	10.3% (149)	0.85 (0.57-1.26)	0.42
Stent thrombosis, definite or probable	1.1% (4)	0.6% (9)	1.93 (0.59-6.26)	0.27
Graft stenosis or occlusion	2.3% (8)	2.7% (39)	0.89 (0.42-1.90)	0.76
Definite stent thrombosis or symptomatic graft occlusion	2.6% (9)	3.1% (45)	0.87 (0.42-1.78)	0.70
TIMI major or minor bleeding	11.1% (39)	6.9% (103)	1.61 (1.12-2.33)	0.01

Values are Kaplan-Meier estimate (number of events). TIMI = Thrombolysis in Myocardial Infarction.

TABLE 4. Thirty-Day Major Adverse Events After PCI Versus CABG in Patients With Versus Without Chronic Kidney Disease

	Chronic Kidney Disease (n = 361)				No Chronic Kidney Disease (n = 1508)			
	PCI (n = 177)	CABG (n = 184)	Hazard Ratio (95% CI)	p-value	PCI (n = 757)	CABG (n = 751)	Hazard Ratio (95% CI)	p-value
Major adverse events, any	10.9% (19)	29.8% (54)	0.36 (0.23-0.59)	<0.0001	6.2% (47)	21.5% (160)	0.29 (0.21-0.39)	<0.0001
Death	1.1% (2)	1.7% (3)	0.69 (0.12-4.08)	1.00	0.3% (2)	1.1% (8)	0.25 (0.05-1.16)	0.06
Myocardial infarction	4.0% (7)	6.6% (12)	0.60 (0.24-1.50)	0.27	3.4% (26)	5.9% (44)	0.58 (0.36-0.94)	0.02
Stroke	1.1% (2)	1.7% (3)	0.69 (0.12-4.08)	1.00	0.3% (2)	1.3% (10)	0.20 (0.04-0.90)	0.02
Transfusion of ≥2 units blood	6.3% (11)	24.3% (44)	0.26 (0.14-0.48)	<0.0001	2.7% (20)	15.6% (116)	0.17 (0.11-0.27)	<0.0001
TIMI major or minor bleeding	3.4% (6)	12.2% (22)	0.28 (0.12-0.68)	0.002	2.7% (20)	8.7% (65)	0.30 (0.19-0.50)	<0.0001
Major arrhythmia	2.3% (4)	19.9% (36)	0.11 (0.04-0.32)	<0.0001	1.7% (13)	13.6% (101)	0.13 (0.07-0.22)	<0.0001
Unplanned coronary revascularization for ischemia	1.1% (2)	2.2% (4)	0.52 (0.10-2.79)	0.69	0.1% (1)	1.1% (8)	0.12 (0.02-0.98)	0.02
Any unplanned surgery or therapeutic radiologic procedure	0.6% (1)	8.3% (15)	0.07 (0.01-0.52)	0.0004	0.9% (7)	2.7% (20)	0.34 (0.15-0.81)	0.01
Acute renal failure*	2.3% (4)	7.7% (14)	0.30 (0.10-0.88)	0.02	0.3% (2)	1.2% (9)	0.22 (0.05-1.01)	0.03
Sternal wound dehiscence	0.0% (0)	3.3% (6)	0.08 (0.00-1.40)	0.03	0.0% (0)	0.4% (3)	0.14 (0.01-2.72)	0.12
Infection requiring antibiotics	2.3% (4)	11.6% (21)	0.20 (0.07-0.56)	0.0006	0.8% (6)	8.2% (61)	0.10 (0.04-0.22)	<0.0001
Intubation for >48 hours	0.6% (1)	3.9% (7)	0.15 (0.02-1.19)	0.07	0.4% (3)	2.4% (18)	0.16 (0.05-0.56)	0.0009
Post-pericardiotomy syndrome	0.0% (0)	0.0% (0)	—	—	0.0% (0)	0.3% (2)	0.20 (0.01-4.10)	0.25

*Defined as a serum creatinine increase of ≥5.0 mg/dL from baseline or a new requirement for dialysis. CABG = coronary artery bypass graft; CI = confidence interval; PCI = percutaneous coronary intervention; TIMI = Thrombolysis in Myocardial Infarction.

TABLE 5. Three-Year Outcomes for PCI Versus CABG in Patients With or Without Chronic Kidney Disease

	Chronic Kidney Disease (n = 361)			No Chronic Kidney Disease (n = 1508)			
	PCI (n = 177)	CABG (n = 184)	Hazard Ratio (95% CI)	PCI (n = 757)	CABG (n = 751)	Hazard Ratio (95% CI)	$P_{interaction}$
Death, stroke, or myocardial infarction	23.1% (40)	18.4% (33)	1.25 (0.79-1.98)	13.4% (100)	13.5% (100)	0.97 (0.73-1.27)	0.36
Death	16.9% (29)	9.0% (16)	1.91 (1.04-3.52)	5.9% (44)	4.9% (36)	1.19 (0.77-1.85)	0.22
Cardiac	8.3% (14)	6.2% (11)	1.34 (0.61-2.94)	3.5% (26)	3.0% (22)	1.15 (0.65-2.04)	0.77
Non-cardiac	9.2% (15)	2.9% (5)	3.15 (1.15-8.68)	2.5% (18)	2.0% (14)	1.25 (0.62-2.52)	0.14
Stroke	3.1% (5)	4.0% (7)	0.75 (0.24-2.36)	2.2% (16)	2.8% (20)	0.78 (0.40-1.50)	0.95
Myocardial infarction	9.5% (16)	8.4% (15)	1.11 (0.55-2.24)	7.7% (57)	8.3% (61)	0.91 (0.63-1.30)	0.62
Death, stroke, myocardial infarction, or IDR	27.2% (47)	21.2% (38)	1.28 (0.84-1.97)	21.8% (163)	18.0% (133)	1.20 (0.95-1.50)	0.77
IDR	10.9% (18)	6.4% (11)	1.74 (0.82-3.68)	13.0% (95)	7.5% (54)	1.75 (1.25-2.44)	0.96
Stent thrombosis, definite or probable	2.3% (4)	—	—	1.2% (9)	—	—	—
Graft occlusion, symptomatic	—	4.5% (8)	—	—	5.4% (39)	—	—
Definite stent thrombosis or symptomatic graft occlusion	0.6% (1)	4.5% (8)	0.13 (0.02-1.03)	0.8% (6)	5.4% (39)	0.15 (0.06-0.35)	0.91
TIMI major or minor bleeding	8.3% (14)	13.8% (25)	0.57 (0.29-1.09)	4.8% (36)	9.0% (67)	0.52 (0.35-0.78)	0.80

Values are Kaplan-Meier estimate (number of events). CABG = coronary artery bypass graft; CI = confidence interval; CKD = chronic kidney disease; IDR = ischemia-driven revascularization; PCI = percutaneous coronary intervention; TIMI = Thrombolysis in Myocardial Infarction.

TABLE 6. Acute renal failure at 30 days in patients with or without CKD undergoing PCI versus CABG.

	Chronic Kidney Disease (n = 361)			No Chronic Kidney Disease (n = 1508)			$p_{interaction}$
	PCI (n = 177)	CABG (n = 184)	Hazard Ratio (95% CI)	PCI (n = 757)	CABG (n = 751)	Hazard Ratio (95% CI)	
Acute renal failure†	2.3% (4)	7.6% (14)	0.28 (0.09-0.87)	0.3% (2)	1.3% (10)	0.20 (0.04-0.90)	0.71
New requirement for dialysis	1.1% (2)	5.4% (10)	0.20 (0.04-0.92)	0.1% (1)	0.5% (4)	0.25 (0.03-2.22)	0.87
Hemodialysis	0.6% (1)	2.7% (5)	0.20 (0.02-1.76)	0.1% (1)*	0.4% (3)	0.33 (0.03-3.18)	0.76
CVVH	0.6% (1)	2.7% (5)	0.20 (0.02-1.76)	0.1% (1)*	0.1% (1)	0.99 (0.06-15.89)	0.38

†Defined as the rise in serum creatinine >5 mg/dL or a new requirement for dialysis. *One patient in the no chronic kidney disease group had both CVVH and hemodialysis. CVVH: Continuous veno-venous hemofiltration.