Coronary Artery Bypass Grafting Versus Percutaneous Coronary Intervention in Coronary Artery Disease Patients with Advanced Chronic Kidney Disease: A Chinese Single-Center Study

Yang Li
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital https://orcid.org/0000-0002-6505-0063
Hongliang Rui
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Zhuhui Huang
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Xiaoyu Xu
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Taoshuai Liu
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Jubing Zheng
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Xuejian Hou
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Shijun Xu
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital
Ran Dong (drdongran@126.com)
Beijing An Zhen Hospital: Capital Medical University Affiliated Anzhen Hospital https://orcid.org/0000-0002-1488-5423

Research article

Keywords: Coronary Artery Bypass Grafting, Percutaneous Coronary Intervention, Chronic Kidney Disease

Posted Date: October 16th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-92124/v1

Abstract

Objectives

Aims to compare the contemporary and long-term outcomes of coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) in coronary artery disease (CAD) patients with advanced chronic kidney disease (CKD).

Design

Observational cohort study, single-center.

Setting

The largest cardiac surgery center in China.

Participants

823 CAD patients with advanced CKD (eGFR<30 ml/min/1.73m^2) were collected, including 247 patients who underwent CABG and 576 patients received PCI from January 2010 to February 2019.

Main outcome measures

The primary end point was all-cause death. The secondary end points included major adverse cardiac and cerebrovascular events (MACCEs), myocardial infarction (MI), stroke and revascularization.

Results

Multivariable Cox regression models were used for risk-adjustment and propensity score matching (PSM) was also performed. After PSM, the 30-day mortality rate in the CABG group was higher than that in the PCI group but without statistically significant (6.6%vs2.4%, p=0.0640). During the first year, patients referred for CABG had a hazard ratio (HR) of 1.42 [95% confidence interval (CI), 0.41–3.01] for mortality compared with PCI. At the end of the 5-year follow-up, CABG group had a HR of 0.58 (95%CI, 0.38-0.86) for repeat revascularization, a HR of 0.77 (95%CI, 0.52-1.14) for survival rate and a HR of 0.88(95%CI, 0.56-1.18) for MACCE as compared to PCI.

Conclusions

Our study suggests that among advanced CKD patients，CABG showed obviously lower risk for repeat revascularization and slightly better prognosis regarding to mortality and other adverse events compared with PCI during the long-term follow-up. At a mean pooled follow-up of one year, both mortality and MACCEs were comparable in both cohorts.

Introduction

The incidence of coronary artery disease (CAD) is increasing by years, the probability of CAD patients combined with advanced chronic kidney disease (CKD) (eGFR < 30 ml/min/1.73 m^2) is higher than 50% [1]. Cardiovascular disease is one of the leading causes of death in patients with advanced CKD[2]. Renal insufficiency increases the risk of death due to revascularization[3]. At present, coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) are the main options for treating patients with vascular disease involving multiple vessels or left main stenosis[4].

CKD patients have complicated etiologies (such as hypertension and diabetes) and severe coronary lesions. Although many comparative studies have proven that CABG has a better long-term prognosis in CKD patients than PCI, prospective randomized controlled trials are still lacking[5, 6]. Most of the studies were conducted in Western or some other Asian countries like Japan and Korea, but it was scarce in China because of the late performance for the cardiac surgery since the 1990s. As one of the largest hospital for the treatment of cardiovascular diseases in China, our center has the capacity to carry out nearly 20,000 revascularization operations each year, and provided rich clinical resources for the coronary revascularization.

The present study retrospectively analyzed the clinical data of advanced CKD patients who underwent CABG and PCI in our hospital and completed short and long-term follow-up, aiming to compare the outcomes of the two surgical approaches, reduce the surgical risks and improve patient prognosis.

Methods

Ethical approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board and Ethics committee of Beijing Anzhen Hospital. Informed written consent was obtained from all patients prior to their enrollment in this study.

Study participants

From January 2010 to February 2019, a total of 823 CAD patients complicated with advanced CKD (eGFR < 30 ml/min/1.73 m^2) were treated at our hospital, including 247 patients who underwent CABG (CABG group) and 576 patients who received PCI (PCI group). Patients who had nephrectomy, kidney transplantation, and combined with valve or other cardiac surgical procedure were excluded. The diagnoses of all patients were confirmed by coronary angiography and included angina, old myocardial infarction (MI), non-ST-segment elevation MI, and ST-segment elevation MI. Data were collected, including preoperative baseline data and intraoperative and postoperative conditions.

Patient and Public Involvement

After the preoperative examination, the patients are evaluated whether they meet the inclusion criteria. If the patients comply with the requirements, explain the relevant contents of the study with the patient and their families. Ensure the patient and their families participating in the study by voluntarily, and let their families sign the informed consent. Then keep the phone number of the patient or family member. Ask the patient regularly whether there are cardiac cerebrovascular events. Before the follow-up date, we will contact the family members or patients, informing them to recheck on time. Explain the current situation of the condition to the patients in detail according to the recheck results, and carry out health education for the patients.

Data collection

Baseline data included age, BMI, sex, eGFR, dialysis, BUN, Hb, family history of coronary heart disease, history of related underlying diseases, smoking history, history of receiving PCI, Canadian Cardiovascular Society (CCS) grading, New York Heart Association (NYHA) functional classification, LVEF, the number of coronary vessels with lesions, and left main coronary artery disease. The surgical conditions included surgical approach, operative time, number of coronary artery anastomoses, number of stents, and intra-aortic balloon pump (IABP) usage rate. Postoperative data included mortality, perioperative MI, stroke, new-onset artificial fibrillation (AF), discharge medications, hospitalization time and cost, mechanical ventilation time, ICU care time, and rates of undergoing thoracotomy for hemostasis in the CABG group, coronary perforation, pericardial tamponade and conversion to emergency CABG in the PCI group. The classic surgical approach was applied for patients in the PCI group. The stents used included drug-eluting and bare-metal stents. The surgical procedures for the CABG group included off-pump coronary artery bypass grafting (OPCABG) and on-pump coronary artery bypass grafting (ON-Pump CABG).

Study end points

The primary endpoint was all-cause deaths. Secondary endpoints included MACCEs, stroke, recurrent MI and repeat revascularization. All follow-up results were obtained by phone or mail from patients themselves and their relatives.

Statistical analysis

For propensity score matching (PSM), the matching conditions included demographic data, such as sex, age and BMI, as well as surgical-related factors, such as eGFR, BUN, Hb, LVEF, history of hypertension, and history of diabetes. Age, BMI, LVEF, eGFR, Hb and ALT were continuous variables; sex, history of hypertension, history of diabetes, history of ischemic stroke, history of AF, history of heart failure, and left main coronary artery (LMCA) disease were categorical variables. Logistic regression analysis was used to establish the CABG propensity score, which was then used for 1:1 matching with the PCI group. When the count data of the two groups followed a normal distribution, the T test was used for analysis; the values are expressed as the mean ± standard deviation. When the data of the two groups did not conform to a normal distribution, the rank sum test was applied; the values are expressed as the median. Measurement data were analyzed with the chi-square test and are expressed as frequencies and percentages. Effects of PCI compared to CABG for individual end points are expressed as HRs with 95% confidence intervals (CIs). All analyses were conducted by a statistician with the use of SAS software version 9.4 (SAS

Institute Inc). All reported p values were 2-sided, and *p* values < 0.05 were regarded as statistically significant.

Results

Baseline Clinical and Procedural Characteristics before PSM

The CABG group had a higher percentage of males, family history of CAD, hemiplegia, history of MI, history of COPD, and history of carotid artery stenosis than the PCI group ($p < 0.05$). The CABG group had lower eGFR and serum cholesterol levels than the PCI group ($p < 0.05$). The number of coronary vessels with lesions and the proportion of coronary artery lesions in CABG group, were all higher than those in the PCI group ($p < 0.01$). The preoperative left ventricular end-diastolic diameter in the CABG group was greater than that in the PCI group ($p = 0.0030$), while there was no significant difference in LVEF between the two groups ($p = 0.41$) (Table 1). In the CABG group, the rate of dialysis was 27.9%, the rate of left internal mammary artery usage and OPCABG ratio were 91.1% and 89.9%, respectively, and the average coronary anastomosis was 3.0 ± 0.8. In the PCI group, the rate of dialysis was 24.5%, the rate of drug-eluting stent (DES) usage was approximately 98.1%, and the average number of implanted stents was 2.6 ± 1.1 (Table 2). Compared with the PCI group, the CABG group had higher in-hospital mortality rate (9.3% vs 1.7%, $p < .001$) and higher incidences of perioperative MI and new-onset AF (18.6% vs 11.8%, $p = 0.009$; 20.6% vs 2.8%, $p < 0.001$). In the CABG group, the ICU care time was 60.8 ± 58.8 h, the ventilator support time was 45.6 ± 42.9 h, and the IABP usage rate was 12.6%. In the PCI group, the proportion of intraoperative complications included coronary artery dissection, perforation and pericardium tamponade were 2.3% (Tables 2 and 3).

Procedural Characteristics and Early outcomes after PSM

166 patients were-well matched in each group. Except for coronary lesions and CCS grading, there were no significant differences in other baseline indicators between the two groups (Table 1). In the CABG group, the mean operative time was 4.3 ± 1.0 h, the average coronary artery bypass anastomosis was 2.9 ± 0.7, and the OPCABG ratio was 90.4%. In the PCI group, the average number of implanted stents was 2.9 ± 1.2 In the CABG group, the percentage of patients who underwent postoperative thoracotomy for hemostasis was 7.8%, the wound infection rate was 4.8%, and the proportion of patients who underwent tracheotomy was 3.6%. Compared with the PCI group, the CABG group had a higher incidence of new-onset AF (25.3%vs4.2%, $p < 0.001$), more support of IABP (13.8%vs3.6%, $p = 0.001$) and higher treatment costs (18230 ± 10421vs10035 ± 5244, $p < 0.001$). The two groups exhibited no significant differences in in-hospital mortality and perioperative complications, such as MI (6.6%vs2.4%, p = 0.07; 17.5% vs12.0%, $p = 0.1637$) (Tables 2 and 3).

Long-term outcomes before PSM

In the CABG group, the 1-year and 5-year survival rates were 92.7% and 72.9%, respectively; the freedom from revascularization were 95.1% and 82.6%, respectively; and the freedom from MACCEs were 85.8%

and 62.7%, respectively. In the PCI group, the 1-year and 5-year survival rates were 93.4% and 66.9%, respectively; the freedom from revascularization were 92.8% and 75.9%, respectively; and the freedom from MACCEs were 88.0% and 60.8%, respectively.

Long-term outcomes after PSM

In the CABG group, the 1-year and 5-year survival rates were 92.1% and 71.6%, respectively; the freedom from revascularization were 96.9% and 83.1%, respectively; the freedom from MACCEs were 87.4% and 63.8%, respectively; the freedom from MI were 95.1% and 88%, respectively and the freedom from stroke were 95.7% and 81.3%, respectively. In the PCI group, the 1-year and 5-year survival rates were 93.9% and 64.5%, respectively; the freedom from revascularization were 94.5% and 72.3%, respectively; the freedom from MACCEs were 89.1% and 59.1%, respectively; the freedom from MI were 96.4% and 78.3%, respectively and the freedom from stroke were 96.9% and 84.9%, respectively (Fig. 1).

During the 1-year follow-up, patients referred for CABG had a slight non-significant increase in the hazard of mortality (HR 1.42; 95%CI, 0.41–3.01), MACCEs (HR 1.22; 95%CI, 0.50–1.82), recurrent MI (HR 1.60; 95%CI, 0.26–3.94) and stroke(HR 1.91; 95%CI, 0.20–4.92) compared with PCI, while the PCI group had higher incidence of repeat revascularization (HR 0.71; 95%CI, 0.21–1.41). At the end of the 5-year follow-up, we found that CABG compared with PCI associated with significantly lower risks for repeat revascularization (HR 0.58; 95%CI, 0.38–0.86; $p = 0.03$). The CABG group had a higher survival rate (HR 0.77; 95%CI, 0.52–1.14), higher freedom from MACCEs (HR 0.88; 95%CI 0.56–1.18), higher freedom from recurrent MI (HR 0.91; 95%CI, 0.49–1.28) and freedom from stroke (HR 0.95; 95%CI, 0.43–1.39) than those in the PCI group but without statistically significant (Fig. 2).

Discussion

Cardiovascular diseases are common complications of CKD and also are the most common cause of death[1]. According to the United States Renal Data System (USRDS), the cardiac mortality accounts for approximately 45%[7]. It is increasingly recognized that patients with advanced CKD who underwent revascularization had worse outcomes than that with normal renal function. However, there is a lack of international guidelines for revascularization therapy for CKD patients in the worldwide.

In our research, patients in the CABG group were relatively young, basically less than 65 years old and were mainly male; the proportion of emergency operations was relatively low, the preoperative cardiac function and size were basically normal, all surgeries were simple bypass surgeries and OPCABG accounted for nearly 90%. The low risk factors and the good preoperative baseline status could have reduced the mortality rates and incidences of complications. There are some studies on the analysis of risk factors for CABG mortality in advanced CKD patients, Li et al.[8] reported 134 cases of dialysis patients who underwent CABG and found that age, history of cerebral stenosis and emergency surgery were risk factors for death. Gautam R. Shroff[9] reported that age over 65 years, white race, peritoneal dialysis and heart failure were independent risk factors for death. ASCERT[10] indicated that the risk factors for death include age, COPD, cerebrovascular diseases, low EF, female, preoperative IABP, CPB, combined surgery, CCS/NYHA grade IV and incomplete vascularization.

The risk of surgery for advanced CKD patients is higher than that for general patients. Valentino Bianco et al.[11] reported that dialysis patients had a higher operative (30-day) mortality (8.6%), higher blood transfusion rate, higher rate of ventilator use for more than 24 h, higher incidence of sternal wound infection, second thoracotomy and new-onset AF. Rahmanian et al.[12] found that the mortality rate for dialysis patients undergoing cardiac surgeries was 3.9 times (12.7%) that for general patients and that dialysis was a risk factor for in-hospital death, which may be due to preoperative dysregulation of blood calcium and phosphorus, abnormal blood lipids and platelet metabolism, and severe coronary artery calcification in ESRD patients. In this study, the in-hospital mortality rate (9.3%) for the CABG group and the incidence of perioperative complications were roughly similar to that previously reported in western countries.

For CAD patients combined with advanced CKD, it is still controversial whether CABG or PCI should be chosen for revascularization. Chung Hee Baek[13] reported that the CABG group had fewer MACCEs than the DES group but that the overall survival rate did not differ. Manabe S[14] reported that the MACCE-free survival rate and angina-free survival rate were significantly higher in patients receiving CABG surgery than in those receiving PCI. Terazawa et al.[15] analyzed 125 dialysis patients who underwent CABG and PCI found that revascularization with CABG was superior to DES. Akira Marui[3] reported that PCI and CABG exhibited no significant difference in all-cause death; however, the PCI group had a higher risk of revascularization than the CABG group. In 2014, ESC/EACTS reported that CABG was superior to PCI for treating CAD patients with moderate to severe renal diseases[16]. In the present study, we found that the two groups exhibited no significant differences at the end of the 1-year follow-up. But during the end of the 5-year follow-up, the CABG group had a better survival rate, higher freedom from MACCEs and freedom from revascularization than the PCI group, indicating that the treatment efficacy of CABG was better than that of PCI.

The long-term survival rate of the CABG group in our study was slightly higher than that reported abroad. Gaudam R. Shroff et al.[9] reported that the 1- and 5-year survival rates in CABG were 70% and 28%, while the DES group had 1- and 5-year survival rates of 71% and 24%, respectively. Leontyev et al.[17] analyzed 483 dialysis patients who underwent CABG and found that the 2, 4, and 6-year survival rates were 64.1%, 42.2%, and 30.6%, respectively. Our finding might be related to the following reasons. First, in our study, the patients had better preoperative biochemical indicators, such as liver function, hemoglobin, albumin, and had basically normal blood lipid levels. Anemia can lead to a series of pathophysiological changes, resulting in reduced quality of life and decreased patient survival. High albumin is a nutritional status and inflammation marker for dialysis patients. The CABG group in this study had hemoglobin levels of 111.29 ± 20.27 g/dl and albumin levels of 38.83 ± 6.02 g/dl, were better that those of patients in the US[18]. Second, the mainly procedure we used was OPCABG, which avoids the use of extracorporeal circulation, reduces the need for blood transfusions and the release of inflammatory mediators, and shortens ventilator assistance and ICU care time. For patients with intolerance due to compromised cardiac function, the timely use of IABP and extracorporeal circulation can ensure the safety of complete revascularization and surgery. Third, the increased survival rate may be related to the race of the patients. Rangrass et al.[19] found that the quality of life of different ethnic groups after CABG treatment varies greatly. For the Asian population, Marui et al.[3] reported that patients with three-vessel disease or left main artery disease have a better 5-year mortality rate, MI rate and revascularization rate after CABG than after PCI. Previous studies also reported that white race is a risk factor for death[10].

The reported mortality rates for dialysis patients in different countries and different regions vary. The Chinese National Renal Data System (CNRDS) reported dialysis patient mortality rates in China in 2007, 2008, 2009 and 2010 of 7.4%, 7.6%, 9.0% and 8.6%, respectively[20], lower than those reported in the United States and Japan. The possible reasons might be dialysis patients in China are generally in good condition, and the average age is relatively low. The most common primary disease is primary glomerular diseases, while in American patients, renal failure is mainly related to diabetes and hypertension[7]. Furthermore, Chinese dialysis patients mostly receive treatment in hospitals, and the contact between doctors and patients is conducive to improving patient compliance and improving long-term prognosis.

The incidence of recent and long-term revascularization in CABG group was significantly better than PCI patients, findings that may be attributable to several factors. First, CABG treatment can provide complete revascularization, however in PCI procedure criminal vessels were always firstly handled. Second, transit time flow measurement was universally used during bypass surgery to ensure long-term patency. Third, preoperative blood glucose and blood lipid levels in patients with CABG were lower than PCI. The increased blood glucose or lipid levels may reduce the patency rate of the graft or the stent.

Recently, ISCHEMIA-CKD study[21] reported that PCI did not reduce the risk of death or nonfatal myocardial infarction in patients with moderate to severe myocardial ischemia compared with drug therapy. However, this study focused on patients with moderate myocardial ischemia (61.4%), with an average follow-up time of only 2.2 years. According to our study, long-term follow-up shows that CABG could improve the prognosis of advanced CKD patients with severe myocardial ischemia, which needs more RCT studies to confirm.

Conclusion

In terms of long-term outcomes, among CAD patients with advanced CKD, CABG associates with a significant decrease in repeat revascularization and might provide slightly better prognosis including overall survival rate, lower risks for stroke and other adverse events as compare to the PCI treatment. Short-term follow-up results reveal that both mortality and MACCE are comparable in both cohorts.

This study has some limitations. First, the data are from a single center and cannot represent the overall situation in China. Second, this is a retrospective study, and there may be selection bias; even PSM cannot completely eliminate bias. Third, there is still a lack of clear revascularization guidelines for CKD or dialysis patient. Finally, the sample size was relatively small, which may affect the applicability of the conclusions and the accuracy of the efficacy analysis. In addition, long-term follow-up results require further analysis.

Abbreviations

CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; CAD: coronary artery disease patients; (CKD) chronic kidney disease; MACCE: Major adverse cardiac and cerebrovascular events; MI: myocardial infarction; PSM: propensity score matching; HR: hazard ratio; CI: confidence intervals; CCS: Canadian Cardiovascular Society; NYHA: New York Heart Association; LVEF: Left ventricular ejection fraction; IABP: Intra-aortic balloon pump; AF: Artificial fibrillation; OPCABG: Off-pump coronary artery bypass grafting; On-pump CABG: on-pump coronary artery bypass grafting; LMCA: Left main coronary artery; DES: Drug-eluting stent; USRDS: United States Renal Data System.

Declarations

Ethics Approval and consent to participate

The Ethics Committee of Beijing Anzhen Hospital and Capital Medical University (Approval Numbers:2010043X) approved the study. Each patient signed informed consent before enrollment.

Consent for Publication

Not applicable

Authors' contributions

LY and RHL was responsible for the design, supervision of the study, and revision of the manuscript. LY drafted the manuscript. HXJ and XSJ designed a statistical plan. DR and LTS and ZJB participated in the revision of the manuscript and the coordination of the study. HZH and XXY participated in data acquisition. All authors read and agreed to the final manuscript.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding

This study was supported by National Natural Science Foundation of China (81570373)

Conflict of interest

The authors report no relationships that could be construed as a conflict of interest.

Acknowledgement

The authors would like to thank all the study subjects for participating in this study as well as all volunteers and the advisers for assisting in collecting the samples and data.

References

1. Hori D, Yamaguchi A, Adachi H: **Coronary Artery Bypass Surgery in End-Stage Renal Disease Patients**. *Ann Vasc Dis* 2017, **10**(2):79-87.
2. Zimmet AD, Almeida A, Goldstein J, Shardey GC, Pick AW, Lowe CE, Jolley DJ, Smith JA: **The outcome of cardiac surgery in dialysis-dependent patients**. *Heart Lung Circ* 2005, **14**(3):187-190.
3. Marui A, Kimura T, Nishiwaki N, Mitsudo K, Komiya T, Hanyu M, Shiomi H, Tanaka S, Sakata R, Investigators CR-KPCRC-: **Five-year outcomes of percutaneous versus surgical coronary revascularization in patients with diabetes mellitus (from the CREDO-Kyoto PCI/CABG Registry Cohort-2)**. *Am J Cardiol* 2015, **115**(8):1063-1072.
4. Giustino G, Mehran R, Serruys PW, Sabik JF, 3rd, Milojevic M, Simonton CA, Puskas JD, Kandzari DE, Morice MC, Taggart DP *et al*: **Left Main Revascularization With PCI or CABG in Patients With Chronic Kidney Disease: EXCEL Trial**. *J Am Coll Cardiol* 2018, **72**(7):754-765.
5. Cooper WA, O'Brien SM, Thourani VH, Guyton RA, Bridges CR, Szczech LA, Petersen R, Peterson ED: **Impact of renal dysfunction on outcomes of coronary artery bypass surgery: results from the Society of Thoracic Surgeons National Adult Cardiac Database**. *Circulation* 2006, **113**(8):1063-1070.
6. Authors/Task Force m, Windecker S, Kolh P, Alfonso F, Collet JP, Cremer J, Falk V, Filippatos G, Hamm C, Head SJ *et al*: **2014 ESC/EACTS Guidelines on myocardial revascularization: The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI)**. *Eur Heart J* 2014, **35**(37):2541-2619.
7. Collins AJ, Foley RN, Chavers B, Gilbertson D, Herzog C, Johansen K, Kasiske B, Kutner N, Liu J, St Peter W *et al*: **'United States Renal Data System 2011 Annual Data Report: Atlas of chronic kidney disease & end-stage renal disease in the United States**. *Am J Kidney Dis* 2012, **59**(1 Suppl 1):A7, e1-420.
8. Li HY, Chang CH, Lee CC, Wu VC, Chen DY, Chu PH, Liu KS, Tsai FC, Lin PJ, Chen SW: **Risk analysis of dialysis-dependent patients who underwent coronary artery bypass grafting: Effects of dialysis modes on outcomes**. *Medicine (Baltimore)* 2017, **96**(39):e8146.
9. 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**(18):1861-1869.
10. Shahian DM, O'Brien SM, Sheng S, Grover FL, Mayer JE, Jacobs JP, Weiss JM, Delong ER, Peterson ED, Weintraub WS *et al*: **Predictors of long-term survival after coronary artery bypass grafting surgery:**

results from the Society of Thoracic Surgeons Adult Cardiac Surgery Database (the ASCERT study). *Circulation* 2012, **125**(12):1491-1500.

11. Bianco V, Kilic A, Gleason TG, Aranda-Michel E, Navid F, Sultan I: **Longitudinal outcomes of dialysis-dependent patients undergoing isolated coronary artery bypass grafting**. *J Card Surg* 2019, **34**(3):110-117.
12. Rahmanian PB, Adams DH, Castillo JG, Vassalotti J, Filsoufi F: **Early and late outcome of cardiac surgery in dialysis-dependent patients: single-center experience with 245 consecutive patients**. *J Thorac Cardiovasc Surg* 2008, **135**(4):915-922.
13. Baek CH, Kim SO, Park SJ, Lee JW, Kim SB, Kim KM: **Propensity-matched comparison of drug-eluting stent implantation and coronary artery bypass graft surgery in chronic hemodialysis patients**. *J Nephrol* 2014, **27**(1):87-93.
14. Manabe S, Shimokawa T, Fukui T, Fumimoto KU, Ozawa N, Seki H, Takanashi S: **Coronary artery bypass surgery versus percutaneous coronary artery intervention in patients on chronic hemodialysis: does a drug-eluting stent have an impact on clinical outcome?** *J Card Surg* 2009, **24**(3):234-239.
15. Terazawa S, Tajima K, Takami Y, Tanaka K, Okada N, Usui A, Ueda Y: **Early and late outcomes of coronary artery bypass surgery versus percutaneous coronary intervention with drug-eluting stents for dialysis patients**. *J Card Surg* 2012, **27**(3):281-287.
16. Chang TI, Shilane D, Kazi DS, Montez-Rath ME, Hlatky MA, Winkelmayer WC: **Multivessel coronary artery bypass grafting versus percutaneous coronary intervention in ESRD**. *J Am Soc Nephrol* 2012, **23**(12):2042-2049.
17. Leontyev S, Davierwala PM, Gaube LM, Rohrig KA, Lehmann S, Holzhey DM, Seeburger J, Noack T, Misfeld M, Mohr FW: **Outcomes of Dialysis-Dependent Patients After Cardiac Operations in a Single-Center Experience of 483 Patients**. *Ann Thorac Surg* 2017, **103**(4):1270-1276.
18. Charytan DM, Pai AB, Chan CT, Coyne DW, Hung AM, Kovesdy CP, Fishbane S, Dialysis Advisory Group of the American Society of N: **Considerations and challenges in defining optimal iron utilization in hemodialysis**. *J Am Soc Nephrol* 2015, **26**(6):1238-1247.
19. Rangrass G, Ghaferi AA, Dimick JB: **Explaining racial disparities in outcomes after cardiac surgery: the role of hospital quality**. *JAMA Surg* 2014, **149**(3):223-227.
20. Zuo L, Wang M: **Current status of maintenance hemodialysis in Beijing, China**. *Kidney International Supplements* 2013, **3**(2):167-169.
21. **Management of Coronary Disease in Patients with Advanced Kidney Disease**. *New England Journal of Medicine* 2020, **383**(11):1090-1092.

Tables

Table 1
Comparison of preoperative baseline characteristics between CABG and PCI groups

Clinical variables	Before PS matched		p-Value	After PS matched		p-Value
	CABG (n = 247)	PCI (n = 576)		CABG (n = 166)	PCI (n = 166)	
Age (years)	64.1 ± 9.3	63.5 ± 12.0	0.44	63.9 ± 9.6	64.4 ± 11.6	0.70
Male (%)	199(80.6)	381(66.1)	< .001	128(77.1)	123(74.1)	0.52
BMI (kg/m^2)	25.5 ± 3.2	26.2 ± 11.6	0.15	25.5 ± 3.3	25.2 ± 3.2	0.41
Family history (%)	14(5.7)	7(1.2)	0.002	6(3.6)	4(2.4)	0.52
Hypertension (%)	196(79.4)	492(85.4)	0.03	130(78.3)	137(82.5)	0.33
Diabetes (%)	100(40.5)	250(43.4)	0.44	65(39.2)	70(42.2)	0.58
Smoking (%)	99(40.1)	191(33.2	0.06	60(36.1)	58(34.9)	0.82
Heart failure (%)	12(4.9)	27(4.7)	0.92	6(3.6)	15(9.0)	0.04
Carotid artery stenosis (%)	43(17.5)	20(3.5)	< .001	12(7.2)	11(6.6)	0.83
NSTEMT	42(17.0)	117(20.3)	0.27	29(17.5)	34(20.5)	0.48
STEMI	23(9.3)	77(13.4)	0.10	16(9.6)	20(12.0)	0.48
Unstable angina pectoris	164(66.4)	346(60.1)	0.09	108(65.1)	102(61.4)	0.49
Emergency surgery (%)	2(0.8)	13(2.3)	0.15	1(0.6)	3(1.8)	0.62
Previous MI (%)	104(42.1)	188(32.6)	0.01	61(36.7)	59(35.5)	0.82
Previous PCI (%)	38(15.4)	99(17.2)	0.68	26(15.7)	23(13.9)	0.64
Previous atrial fibrillation (%)	13(5.3)	41(7.1)	0.32	8(4.8)	14(8.4)	0.19
Previous TIA or stroke (%)	31(12.6)	76(13.2)	0.80	18(10.8)	21(12.7)	0.61
Hemoglobin(g/l)	111.3 ± 20.3	111.7 ± 23.1	0.81	112.4 ± 21.0	110.5 ± 23.8	0.44
Albumin(mmol/L)	38.8 ± 6.0	41.8 ± 9.1	< .001	39.1 ± 5.7	40.9 ± 9.2	0.09

The data are shown as mean ± SD or n (%).CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; eGFR: Evaluated glomerular filtration rate; BMI: Body mass index; MI: Myocardial infarction; TIA: Transient ischemic attack; ALT: Alanine aminotransferase; LVEDD: Left ventricular end-diastolic dimension; LVEF: Left ventricular ejection fraction; NYHA: New York Heart Association; CCS: Canadian Cardiovascular Society; STEMI: ST-elevation myocardial infarction; NSTEMI: Non-STEMI; LAD: Left anterior descending artery; LCX: Left circumflex; PDA: Posterior descending artery; PLA: Posterior left ventricle artery; RCA: Right coronary artery; SD: Standard deviation.

Clinical variables	Before PS matched		p-Value	After PS matched		p-Value
	CABG (n = 247)	PCI (n = 576)		CABG (n = 166)	PCI (n = 166)	
Triglyceride(mmol/L)	2.3 ± 1.5	2.3 ± 2.0	0.93	2.2 ± 1.3	2.1 ± 1.9	0.73
Cholesterol(mmol/L)	4.4 ± 1.2	4.7 ± 1.3	0.01	4.5 ± 1.2	4.7 ± 1.4	0.10
eGFR(ml/(min·1.73 m^2))	8.3 ± 3.3	10.2 ± 4.5	< .001	8.7 ± 3.2	9.0 ± 4.4	0.54
CKD stage (%)						
4 and 5 (GFR < 29)	178(72.1)	435(75.5)	0.52	122(73.5)	126(75.9)	0.84
5D (dialysis)	69(27.9)	141(24.5)	0.30	44(26.5)	40(24.1)	0.71
Calcium(mmol/L)	2.1 ± 0.4	2.1 ± 0.2	0.75	2.2 ± 0.4	2.1 ± 0.2	0.15
Left main stenosis (%)	32(13.0)	51(8.9)	0.07	24(14.5)	23(13.9)	0.87
No. of narrowed coronary arteries	3.1 ± 0.79	2.5 ± 0.98	< .001	2.9 ± 0.78	3.0 ± 0.99	0.30
1 (%)	11(4.4)	94(16.3)		9 (5.4)	10 (6)	
2 (%)	31(12.6)	201(34.9)		38 (22.9)	25 (15.1)	
3 (%)	141(57.1)	206(35.8)		75 (45.2)	102 (61.4)	
≥ 4 (%)	64(25.9)	75(13.0)		44 (26.5)	29 (17.5)	
Artery intervention (%)						
LAD	243(98.4)	491(85.2)	< .001	164(98.8)	150(90.4)	0.00
D	91(36.8)	106(18.4)	< .001	54(32.5)	44(26.5)	0.23
LCX	198(80.2)	332(57.6)	< .001	126(75.9)	122(73.5)	0.61
PDA	162(65.6)	93(16.1)	< .001	102(61.4)	43(25.9)	< .001
PLA	63(25.5)	41(7.1)	< .001	44(26.5)	17(10.2)	0.001
RCA	175(70.9)	368(63.9)	0.05	109(65.7)	120(72.3)	0.19
LVEDD	52.9 ± 6.7	51.3 ± 7.2	0.003	52.1 ± 6.8	52.2 ± 7.1	0.84

The data are shown as mean ± SD or n (%).CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; eGFR: Evaluated glomerular filtration rate; BMI: Body mass index; MI: Myocardial infarction; TIA: Transient ischemic attack; ALT: Alanine aminotransferase; LVEDD: Left ventricular end-diastolic dimension; LVEF: Left ventricular ejection fraction; NYHA: New York Heart Association; CCS: Canadian Cardiovascular Society; STEMI: ST-elevation myocardial infarction; NSTEMI: Non-STEMI; LAD: Left anterior descending artery; LCX: Left circumflex; PDA: Posterior descending artery; PLA: Posterior left ventricle artery; RCA: Right coronary artery; SD: Standard deviation.

Clinical variables	Before PS matched		*p*-Value	After PS matched		*p*-Value
	CABG (n = 247)	PCI (n = 576)		CABG (n = 166)	PCI (n = 166)	
Ventricular aneurysm (%)	17(6.9)	53(9.2)	0.27	11(6.6)	18(10.8)	0.17
LVEF	55.4 ± 10.4	54.7 ± 11.9	0.41	54.8 ± 0.8	56.2 ± 12.0	0.27
NYHA classification (%)			0.002			0.22
1	12(4.9)	41(7.1)		7(4.2)	15(9.0)	
2	136(55.1)	363(63.0)		98(59.0)	95(57.2)	
3	81(32.8)	118(20.5)		50(30.1)	41(24.7)	
4	18(7.3)	54(9.4)		11(6.6)	15(9.0)	
CCS classification (%)			< .001			0.02
1	1(0.4)	18(3.1)		1(0.6)	4(2.4)	
2	155(62.8)	427(74.1)		104(62.7)	123(74.1)	
3	68(27.5)	73(12.7)		45(27.1)	24(14.5)	
4	23(9.3)	58(10.1)		16(9.6)	15(9.0)	

The data are shown as mean ± SD or n (%).CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; eGFR: Evaluated glomerular filtration rate; BMI: Body mass index; MI: Myocardial infarction; TIA: Transient ischemic attack; ALT: Alanine aminotransferase; LVEDD: Left ventricular end-diastolic dimension; LVEF: Left ventricular ejection fraction; NYHA: New York Heart Association; CCS: Canadian Cardiovascular Society; STEMI: ST-elevation myocardial infarction; NSTEMI: Non-STEMI; LAD: Left anterior descending artery; LCX: Left circumflex; PDA: Posterior descending artery; PLA: Posterior left ventricle artery; RCA: Right coronary artery; SD: Standard deviation.

Table 2

Comparison of perioperative data between CABG and PCI groups

Procedural variables	Before PS matched		After PS matched	
	CABG (n = 247)	PCI (n = 576)	CABG (n = 166)	PCI (n = 166)
Duration of operation(h)	4.3 ± 1.0	-	4.2 ± 1.0	-
Number of grafts	3.0 ± 0.8	-	2.9 ± 0.7	-
Number of stents	-	2.6 ± 1.1		2.9 ± 1.2
LITA usage (%)	225(91.1)	-	152 (91.6)	-
OPCABG (%)	222(89.9)	-	150(90.4)	-
Drug-eluting stent usage (%)	-	565(98.1)	-	163(98.2)
Coronary artery dissection (%)	-	4 (0.7)	-	2(1.2)
Coronary perforation (%)	-	5 (0.9)	-	3(1.8)
Pericardium tamponade (%)	-	4 (0.7)	-	3(1.8)

CABG: coronary artery bypass grafting; PCI: Percutaneous coronary intervention; Left internal thoracic artery: LITA

Table 3
Comparison of postoperative data between CABG and PCI groups

Postoperative variables	**Before PS Matched**		***p*-Value**	**After PS Matched**		***p*-Value**
	CABG (n = 247)	**PCI (n = 576)**		**CABG (n = 166)**	**PCI (n = 166)**	
ICU time(h)	60.8 ± 58.8	-		61.4 ± 58.7	-	
Mechanic ventilation time(h)	45.6 ± 42.9	-		45.4 ± 41.3	-	
IABP (%)	31(12.6)	18(3.1)	< .001	23 (13.8)	6 (3.6)	0.001
Red Blood cell transfusion(U)	3.4 ± 2.8	-		3.5 ± 2.9	-	
Reoperation for bleeding (%)	21(8.5)	-		13 (7.8)	-	
Re-intubation (%)	12(4.9)	-		9 (5.4)	-	
Wound complications (%)	12(4.9)	-		8 (4.8)	-	
Tracheotomy (%)	10(4.0)	-		6 (3.6)	-	
Myocardial infarction (%)	46(18.6)	68(11.8)	0.009	29 (17.5)	20(12.0)	0.16
Cerebral infarction (%)	2(0.8)	11(1.9)	0.25	1 (0.6)	2(1.2)	1
Infection (%)	16(6.5)	10(1.7)	< .001	9 (5.4)	4(2.4)	0.16
New-Onset AF (%)	51(20.6)	16(2.8)	< .001	42(25.3)	7(4.2)	< .001
Cost (USD)	18909 ± 12599	8876 ± 4521	< .001	18230 ± 10421	10035 ± 5244	< .001
Inhospital mortality (%)	23(9.3)	10(1.7)	< .001	11 (6.6)	4 (2.4)	0.07
Medication at discharge (%)						
Aspirin	220(96.5)	544(96.3)	0.89	153 (96.8)	159 (98.1)	0.50
Clopidogrel	181(79.3)	510(90.3)	0.002	127 (76.5)	143 (88.3)	< .001
Beta-blockers	199(87.3)	514(91.0)	0.12	136 (86.1)	144 (88.9)	0.45
Statin	171(75.0)	528(93.5)	< .001	122 (77.2)	153 (94.4)	< .001
Nitrates	196(86.0)	423(74.9)	< .001	137 (86.7)	128 (79.0)	0.07

The data are shown as mean ± SD or n (%). *Compared by paired t-test; otherwise by McNemar's test or Fisher's exact test. CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; IABP: Intra-aortic balloon pump; AF: Atrial fibrillation; SD: Standard deviation.

Figures

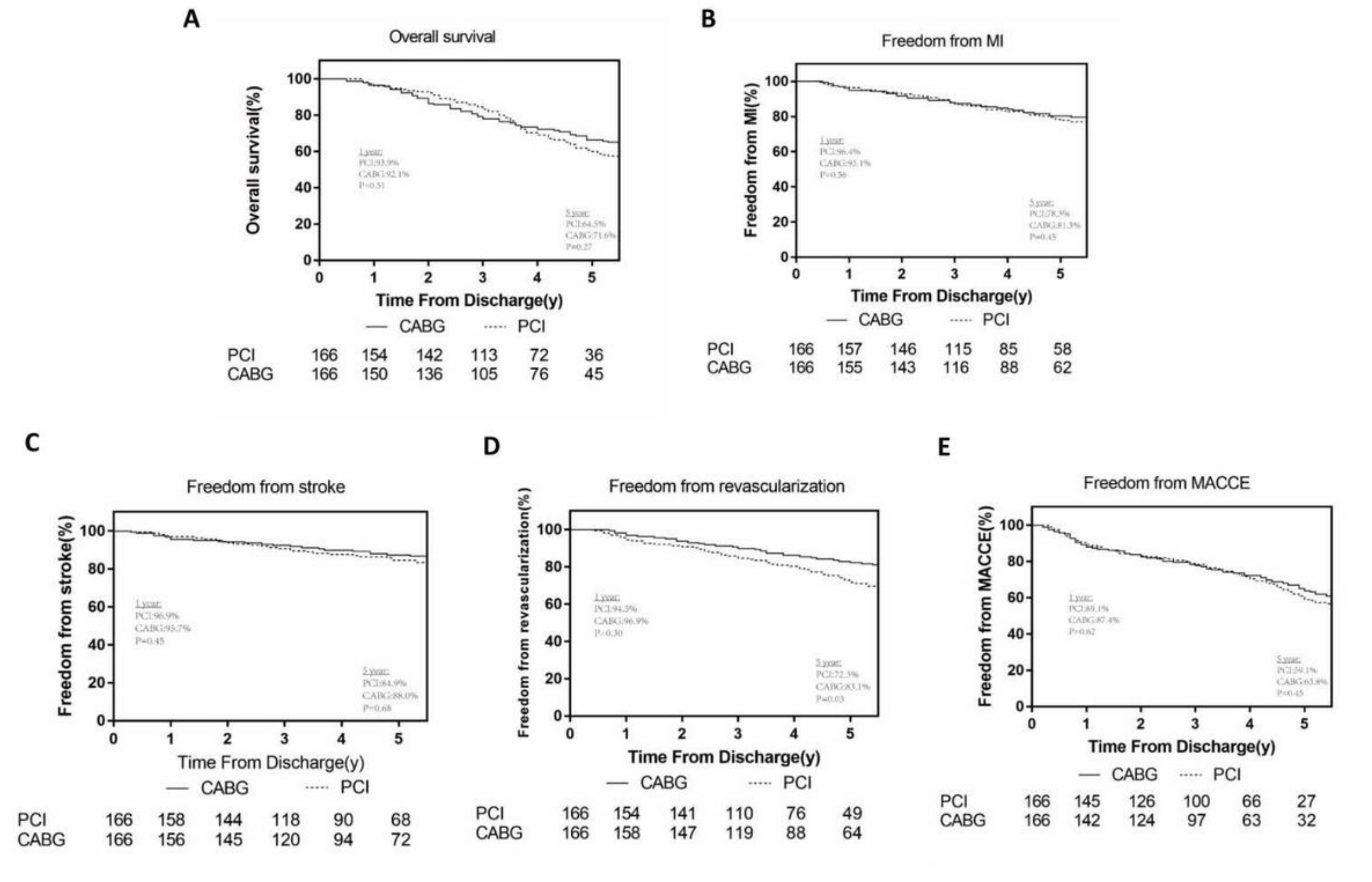

Figure 1

The comparson of survival and MACCEs at 1-year and 5-years between the two groups.

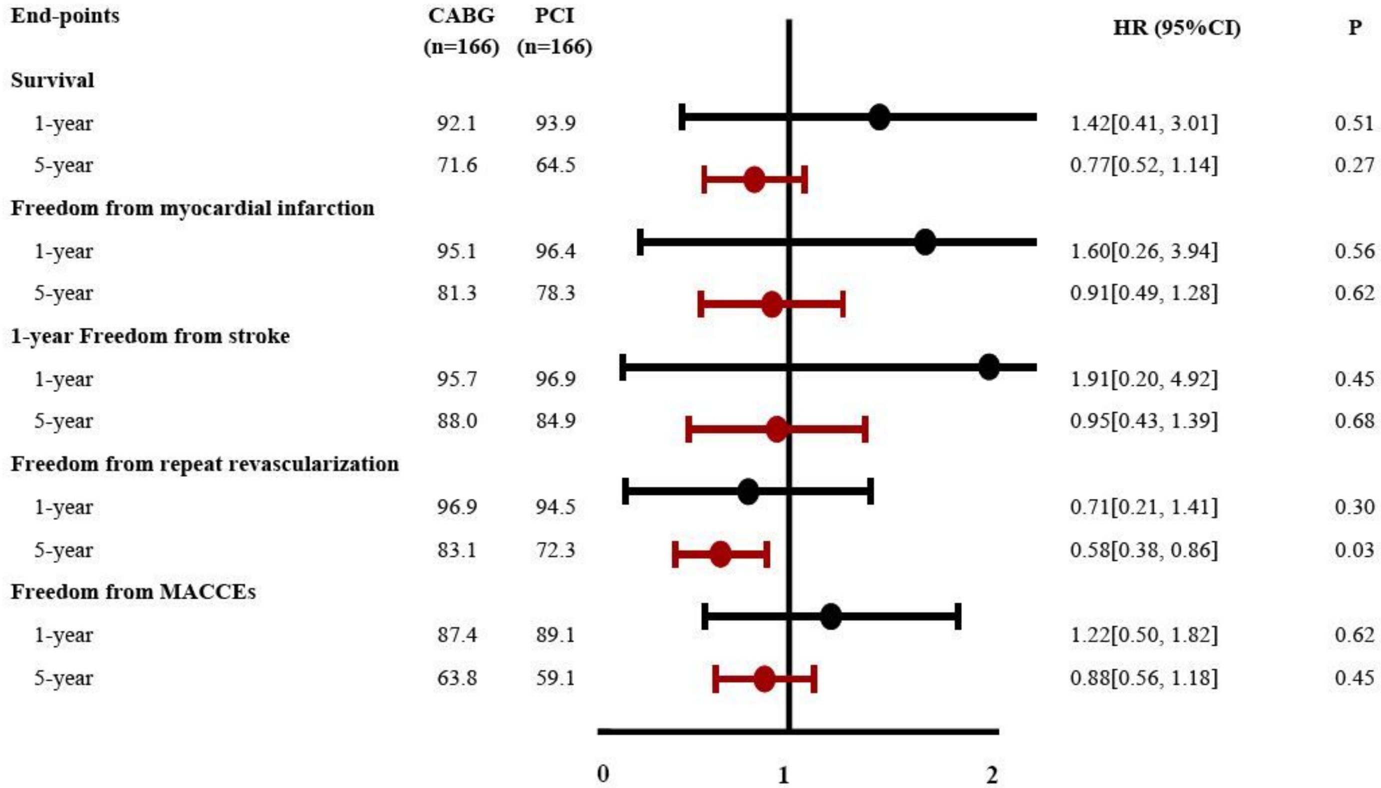

Figure 2

Cumulative event curves for outcomes of survival, freedom from myocardial infarction, freedom from stroke, freedom from repeat revascularization and freedom from major adverse cardiovascular and cerebrovascular events(A–E). Curves generated using the Kaplan–Meier approach Forest plot showing associations for different endpoints. Hazard ratios and 95% confidence intervals generated from Cox proportional hazards regression without covariate adjustment. Black squares and lines show point estimates and 95% CI for patients with PCI while Red squares and lines reflect associations for patients with CABG.