

An optimal strategy for coronary revascularization in patients with severe renal dysfunction

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Abstract

OBJECTIVES: The optimal strategy for coronary revascularization in patients with renal dysfunction remains undefined. As coronary artery bypass grafting (CABG) may be associated with higher mortality, less invasive percutaneous coronary intervention (PCI) may be preferred. To date, only limited information has been published regarding the effects of severe renal dysfunction on the outcome after CABG and PCI. To address this limitation, we analysed the clinical outcomes after CABG or PCI in patients with severe renal dysfunction not on chronic haemodialysis (HD).

METHODS: Among patients enrolled in the CREDO-Kyoto (Coronary Revascularization Demonstrating Outcome Study in Kyoto) Registry (a multicentre PCI/CABG registry in Japan), we identified 374 patients with multivessel disease and an estimated glomerular filtration rate $<30 \text{ ml min}^{-1} 1.73 \text{ m}^{-2}$ (PCI: $n = 229$, CABG: $n = 145$). Patients with acute myocardial infarction ($n = 221$) were excluded. Then, 77 pairs were selected for further analysis using propensity score matching. The median follow-up was 2.5 years.

RESULTS: In-hospital deaths following CABG (2, 2.6%) and PCI (4, 5.2%) did not differ significantly between groups ($P = 0.46$). Deterioration of renal function during hospitalization occurred in 9 and 5% of the CABG and PCI groups, respectively ($P = 0.35$). The rate of early introduction of HD did not differ between groups: CABG, 8%; PCI, 9%. Long-term survival was not different between CABG and PCI. However, freedom from major adverse cardiac and cerebrovascular events (log-rank, $P = 0.003$) and target lesion revascularization (log-rank, $P = 0.003$) was markedly higher in CABG.

CONCLUSIONS: Despite the marked progress in PCI technologies and techniques, CABG remains the standard treatment in patients with coronary artery disease complicated by severe renal dysfunction.

Keywords: Acute coronary syndrome • Coronary artery bypass grafts • Renal dysfunction

INTRODUCTION

The rate of cardiovascular events increases substantially with a progressively lower estimated glomerular filtration rate (eGFR) [1]. Chronic kidney disease (CKD) is a well-recognized risk factor for postoperative morbidity and mortality after coronary artery bypass grafting (CABG) [2] with operative mortality rates being 4- to 5-fold higher in patients with advanced CKD [3]. Moreover, surgical intervention is believed to precipitate permanent haemodialysis (HD). As CKD patients are often denied or not referred for surgical revascularization, they may prefer a less invasive alternative such

as percutaneous coronary intervention (PCI), potentially associated with lower procedural mortality.

We previously reported that CABG was superior to PCI with drug-eluting stents (DES) in patients with chronic renal failure on HD in terms of long-term outcomes for cardiac death, major adverse cardiac events and target lesion revascularization (TLR) [4]. A meta-analysis of retrospective observational trials shows that CABG would be the preferred revascularization strategy for end-stage renal disease, owing to an acceptable short-term mortality and the lower rates of long-term mortality and cardiac events [5].

On the other hand, limited information has been published regarding the effects of severe renal dysfunction on the outcome after CABG and PCI. Reddan *et al.* reported that, among patients with severe CKD, PCI was not associated with improved survival compared with medical management; however, CABG was associated with greater reduction in the mortality rate compared with PCI [6]. Another report also showed that compared with medication, CABG was associated with better survival in non-HD severe CKD patients, unlike PCI [7]. A retrospective cohort study of patients from the New York Department of Health databases showed that CABG did not convey a survival benefit over PCI in patients with severe CKD [8]. In the DES era, non-HD moderate or severe CKD patients with triple-vessel disease who underwent CABG tended to have a lower long-term mortality rate than those who underwent PCI. However, these CABG patients had a greater short-term risk of requiring permanent HD [9].

Previous studies have been limited by their inability to adjust for clinical variables such as severity of coronary artery disease. An apparent selection bias favours PCI for patients with single-vessel disease, and CABG for those with left main and triple-vessel disease. Therefore, we determined the optimal strategy of coronary revascularization for patients with severe renal dysfunction using propensity score-matching analysis using data from the CREDO-Kyoto PCI/CABG Registry (Coronary Revascularization Demonstrating Outcome Study in Kyoto) Cohort 2, a multicentre PCI/CABG registry in Japan with 15 939 patients.

PATIENTS AND METHODS

The CREDO-Kyoto PCI/CABG Registry Cohort 2 is a physician-initiated multicentre registry that enrolled consecutive patients who underwent their first coronary revascularization either with CABG or PCI, between January 2005 and December 2007. The study design and patient enrolment of the registry were previously described [10]. The relevant ethics committees in all 26 participating centres approved the research protocol. Because the study subjects were retrospectively enrolled, written informed consent was not obtained. The cohort consisted of 15 939 patients, recruited from 26 centres in Japan. Sixty-seven patients refused participation when contacted for follow-up, and were excluded from further study. Those patients who had concomitant non-coronary surgery ($n = 609$), or for whom there were insufficient data to calculate the eGFR ($n = 170$), were also excluded. From the remaining cohort, we identified 756 non-dialysis-dependent eligible patients with an eGFR $<30 \text{ ml min}^{-1} 1.73 \text{ m}^{-2}$ (Fig. 1). Of these, patients with single-vessel disease ($n = 161$) and acute myocardial infarction (MI; $n = 221$) were excluded. A total of 374 patients (PCI: $n = 229$, CABG: $n = 145$) were included in the present study (Fig. 2). The SYNTAX score was calculated for patients with triple-vessel disease and left main artery disease.

Renal function definition

The eGFR was calculated using the Modification of Diet in Renal Disease (MDRD) Study equation using the Japanese Society of Nephrology-Chronic Kidney Disease Initiatives coefficient, since the original MDRD Study equation has shortcomings in GFR estimation for Asian populations [11].

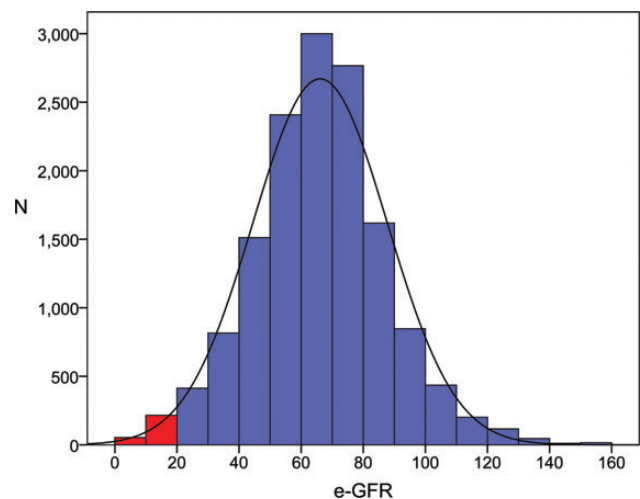


Figure 1: Distribution of eGFR among patients enrolled in the CREDO-Kyoto PCI/CABG Registry. Cohort 2 consisted of 15 939 patients; 603 patients who were dialysis-dependent were not incorporated. The study groups with an eGFR $<30 \text{ ml min}^{-1} 1.73 \text{ m}^{-2}$ are indicated. eGFR: estimated glomerular filtration rate; CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention.

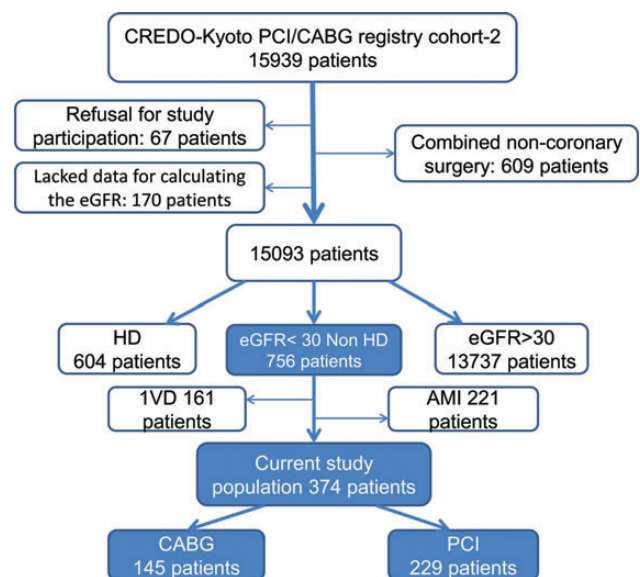


Figure 2: Study flow-chart. eGFR: estimated glomerular filtration rate; CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention; AMI: acute myocardial infarction; HD: haemodialysis; 1VD: single-vessel disease.

The eGFR equation used in this study is as follows:

$$\text{eGFR (male)} : 0.741 \times 175 \times \text{age}^{-0.203} \times \text{serumcreatinine}^{-1.154}$$

$$\text{eGFR (female)} : 0.741 \times 175 \times \text{age}^{-0.203}$$

$$\times \text{serumcreatinine}^{-1.154} \times 0.742$$

The serum creatinine concentration is in mg/dl and age is in years.

The creatinine value at hospital admission was adopted for calculation of the eGFR.

Study end-points

The primary clinical end-point was freedom from major adverse cardiac and cerebrovascular events (MACCEs) defined as all-cause death, MI, stroke and any revascularization. Death was regarded as cardiac in origin unless obvious non-cardiac causes could be identified. MI was defined according to the definition used in the Arterial Revascularization Therapy Study [12]. Stroke was defined as an ischaemic or haemorrhagic stroke with symptoms lasting more than 24 h either during the index hospitalization for the initial coronary revascularization or requiring hospitalization during follow-up. TLR was defined as any revascularization performed on the treated lesion. Scheduled staged PCI procedures performed during the index hospitalization or within 3 months of the initial procedure were not regarded as revascularization. Significant deterioration of renal function after the coronary revascularization procedures was defined as a maximal serum creatinine value more than twice the basal level.

Follow-up

Follow-up information was collected mainly through a hospital chart review by clinical research coordinators from an independent research organization (Research Institute for Production Development, Kyoto, Japan). Additional follow-up information was collected through a questionnaire sent by mail to patients, relatives and/or referring physicians. Death, MI and stroke were adjudicated by a clinical event committee.

Because final data collection for follow-up events was initiated on 1 July 2009, follow-up events were censored on this date. The median follow-up duration was 875 days. Complete 1-year follow-up information was obtained in 93.6% of patients (92.4% in the CABG group and 94.3% in the PCI group, $P = 0.46$).

Statistical analysis

Categorical variables were presented as percentage and compared using the χ^2 test. Continuous variables were expressed as mean $\pm$ standard deviation (SD) and compared using Student's *t*-test. Survival and event-free survival were analysed using the Kaplan-Meier method. The log-rank test was used to assess the difference between groups.

Propensity scores, which were the probabilities that a patient would undergo PCI, were calculated for 374 patients in the study group. Confounding factors in the logistic regression model included age, sex, emergency procedure, prior MI, history of congestive heart failure, stroke, peripheral arterial disease, atrial fibrillation, chronic obstructive pulmonary disease, malignancy, dyslipidaemia treated with medication, hypertension, diabetes mellitus, current smoker status, eGFR, triple-vessel disease and left main trunk disease. For the matching process, the nearest neighbour matching within a caliper width of 0.01 was used.

A multivariable Cox proportional hazards model was constructed to evaluate the hazard ratio for mortality and MACCEs, adjusted for a set of covariates that were selected in a step-wise fashion by the use of backward elimination. SYNTAX score was not introduced into the model because the data for double-vessel disease were missing.

Statistical analyses were conducted by physicians (Tatsuhiko Komiya and Go Ueno) and supervised by a statistician (Shiro Tanaka) using SPSS Statistics 19 (IBM Corporation, Armonk, New York, NY, USA). The authors had full access to the data and take responsibility for their integrity.

RESULTS

Baseline characteristics

Among 374 patients with severe renal dysfunction, 145 patients were treated with CABG, and 229 with PCI. Baseline characteristics of the patients in both groups are given in Table 1. Patient history of stroke, liver cirrhosis, malignancy and peripheral arterial disease did not differ between the groups. The PCI group included a greater number of patients with chronic obstructive pulmonary disease. Moreover, the PCI group included less patients with complex coronary artery lesions such as triple-vessel disease or left main disease. The SYNTAX score was not different between the groups.

Propensity score matching

Seventy-seven pairs were selected for further analysis using propensity score matching. The median follow-up was 919 days after matching. Complete 1-year follow-up information was obtained in 94.8% of patients (94.8% in the CABG group and 94.8% in the PCI group). The baseline characteristics of these 77 pairs were not significantly different between the CABG and PCI groups, including the SYNTAX score (Table 1). In the CABG group, the ratios of off-pump technique use, and the graft material were not different before and after matching. In the PCI group, the prevalence of DES use was not different; however, the total number of stents became greater after matching. The numbers of target vessels and target lesions were larger in the CABG group before and after matching ($P < 0.001$). Staged PCI was performed in $\sim 25\%$ of patients (Table 2).

Clinical outcomes within 1 year (matched group)

In-hospital death was 2 (2.6%) in the CABG group, and 4 (5.2%) in the PCI group ($P = 0.46$). In the CABG group, one patient developed perioperative MI and died after removal of the haematoma in the chest cavity, and another died suddenly on postoperative day 5. In the PCI group, one patient developed periprocedural MI and died on postoperative day 5. Another patient with aggravating congestive heart failure did not recover from a state of cardiogenic shock. One patient died of sepsis and the other died from cerebral bleeding. Stent thrombosis was not observed in the study group.

During hospitalization the maximum creatinine level was 3.2 ± 1.9 in CABG and 2.7 ± 1.4 mg/dl in PCI ($P = 0.13$) (Fig. 3). A significant deterioration of renal function occurred in 9% of the CABG group, and 5% of the PCI group ($P = 0.35$). The early introduction rate of HD (< 90 days from revascularization) was not different: 8% for CABG and 9% for PCI patients.

During the first year, the revascularization rate was much higher in the PCI group. One-year event rates are summarized in Table 3.

Table 1: Baseline characteristics

	Before matching			After matching		
	CABG (n = 145)	PCI (n = 229)	P value	CABG (n = 77)	PCI (n = 77)	P value
Age (years)	70.9 ± 8.9	74.7 ± 9.4	0.001	72.7 ± 7.1	72.7 ± 9.4	0.97
Male (%)	91 (63%)	132 (58%)	0.33	44 (57%)	48 (62%)	0.51
2VD (%)	6 (4%)	107 (47%)	<0.001	6 (8%)	9 (12%)	0.67
3VD (%)	101 (70%)	103 (45%)	<0.001	57 (74%)	55 (71%)	0.72
LMT disease (%)	38 (26%)	19 (8%)	<0.001	14 (18%)	13 (17%)	0.83
Prior MI (%)	43 (30%)	58 (25%)	0.36	19 (25%)	22 (29%)	0.58
Emergent (%)	6 (4%)	9 (4%)	0.92	4 (5%)	2 (3%)	0.40
CHF (%)	22 (15%)	44 (19%)	0.32	20 (26%)	20 (26%)	1.0
Stroke (%)	28 (19%)	52 (23%)	0.44	14 (18%)	21 (27%)	0.18
Atrial fibrillation (%)	26 (18%)	22 (10%)	0.02	13 (17%)	9 (12%)	0.36
COPD (%)	2 (1%)	15 (7%)	0.02	2 (3%)	2 (3%)	1.0
Liver cirrhosis (%)	2 (1%)	7 (3%)	0.30	1 (1%)	2 (3%)	0.56
Malignancy (%)	20 (14%)	23 (10%)	0.27	12 (16%)	9 (12%)	0.48
PAD (%)	18 (12%)	35 (15%)	0.44	9 (12%)	13 (17%)	0.36
Hypertension (%)	133 (92%)	219 (96%)	0.12	73 (95%)	70 (91%)	0.35
Dyslipidaemia (%)	72 (50%)	96 (42%)	0.14	39 (51%)	35 (45%)	0.52
Current smoking (%)	32 (22%)	45 (20%)	0.57	17 (22%)	16 (21%)	0.84
Diabetes mellitus (%)	93 (64%)	133 (58%)	0.24	44 (57%)	49 (64%)	0.41
Creatinine (mg/dl)	2.3 ± 0.9	2.6 ± 1.3	0.24	2.3 ± 1.1	2.4 ± 1.3	0.43
eGFR (mL min ⁻¹ 1.73 m ⁻²)	21.4 ± 6.0	21.0 ± 6.8	0.58	21.2 ± 6.3	22.5 ± 6.6	0.21
BUN (mg/dl)	35.3 ± 11.1	40.1 ± 17.1	0.003	35.7 ± 11.7	38.1 ± 16.1	0.30
SYNTAX score	30.9 ± 9.9	28.9 ± 11.3	0.31	30.1 ± 12.3	28.6 ± 12.1	0.46

CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention; 3VD: triple-vessel disease; LMT: left main trunk; LAD: left anterior descending artery; MI: myocardial infarction; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; PAD: peripheral arterial disease; eGFR: estimated glomerular filtration rate; BUN: blood urea nitrogen.

Table 2: CABG and PCI details

	Before matching		P value	After matching		P value
	CABG	PCI		CABG	PCI	
n	145	229		77	77	
OPCAB	102 (70%)			50 (65%)		
BITA	32 (22%)			15 (19%)		
Radial artery	15 (10%)			6 (8%)		
Gastric epiploic artery	46 (32%)			24 (31%)		
Total arterial grafts	51 (35%)			24 (31%)		
Drug-eluting stent		158 (69%)			58 (75%)	
Bare metal stent		62 (27%)			16 (21%)	
Total number of stents		2.2 ± 1.3			2.6 ± 1.5	
Staged PCI		53 (23%)			22 (29%)	
Target vessels	2.6 ± 0.6	1.5 ± 0.6	<0.001	2.6 ± 0.6	1.6 ± 0.7	<0.001
Target lesions	3.2 ± 1.2	1.6 ± 0.7	<0.001	3.1 ± 1.0	1.6 ± 0.8	<0.001

CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention; OPCAB: off-pump coronary artery bypass; BITA: bilateral internal thoracic artery.

Long-term follow-up outcomes (matched group)

The rate of freedom from MACCEs was significantly higher in the CABG group than in the PCI group (1 year: 82.7 vs 69.4%, and 3 years: 78.9 vs 47.4%, $P = 0.003$). There was a marked difference in the rate of freedom from TLR (1 year: 98.7 vs 88.4%, and 3 years: 98.7 vs 81.2%, $P = 0.003$) (Fig. 4). There was no significant difference in the rate of freedom from MI (1 year: 100 vs 98.6%, and 3 years: 100 vs 98.6%, $P = 0.31$) and stroke (1 year: 91.6 vs 91.6%, and 3 years: 86.6 vs 88.1%, $P = 0.67$). Regarding survival, the rates of

freedom from all-cause death (1 year: 92.0 vs 85.7%, and 3 years: 78.9 vs 74.6%, $P = 0.28$) and freedom from cardiac death (1 year: 93.3 vs 89.5%, and 3 years: 89.5 vs 84.7%, $P = 0.18$) (Fig. 4) were not statistically different between the CABG and PCI groups. The creatinine value at the last follow-up was not different between the groups (2.6 ± 1.8 vs 2.8 ± 1.8 mg/dl, $P = 0.58$) (Fig. 3).

The Cox multivariate proportional hazard model indicated that prior MI and peripheral arterial disease were independent risk factors for cardiac death, and CABG was not. However, for MACCEs, CABG was strongly associated with a reduction in risk.

Interestingly, treated dyslipidaemia and history of stroke were both associated with a reduction in risk (Table 4).

DISCUSSION

The present study aimed to determine the optimal revascularization strategy for patients with severe renal dysfunction. As there was marked heterogeneity in the baseline characteristics between the CABG and PCI groups, a propensity score-matching analysis was used. In-hospital mortality was not different between the CABG and PCI groups. Deterioration of renal function during hospitalization was slightly higher for the CABG group; however, the rate of early introduction of HD did not differ between groups. Although mid-term survival was not different between CABG and PCI, the rate of freedom from MACCEs and TLR was markedly higher after CABG.

Renal dysfunction is associated with other disease processes such as diabetes mellitus and hypertension that are determinants of poorer outcome. Accelerated atherogenesis among patients with renal failure can be explained by these associated diseases [8]. A high prevalence rate of diabetes mellitus of up to 65% was observed in our study cohort. Diabetes and CKD work synergistically to increase the risk of adverse outcomes after PCI and CABG. Extensive atherosclerosis as evidenced by the increasing percentage of concomitant peripheral vascular disease was noted as a

function of worsening renal dysfunction. Renal failure patients tend to have more advanced degrees of atherosclerosis and calcification of coronary vessels and the aorta; therefore, they are a technically more challenging subset of patients for CABG [13]. The operative mortality of CABG rose inversely with declining renal function, from 1.3% for patients with normal renal function to 9.3% for those with non-HD severe renal dysfunction and 9.0% for those who were HD dependent. Stroke, septicemia, reoperation for bleeding and prolonged ventilation were highest in severe renal dysfunction or dialysis [2]. Another report also mentioned high operative mortality in severe renal failure [3]. The operative mortality in our series was lower than that in previous reports.

On the other hand, patients with end-stage renal dysfunction are known to be at high risk of restenosis after PCI even if treated with DESs [5]. PCI in patients with CKD is a high-risk procedure due to an increased incidence of acute renal failure, restenosis and mortality [14]. Also, CKD has been described as a risk factor for stent thrombosis [15]. Among patients with severe CKD, PCI was not associated with improved survival compared with medical management [6]. In patients with moderate-to-severe renal dysfunction who received DESs, there was no long-term survival benefit compared with bare metal stents [16]. Previous studies comparing PCI and CABG in CKD demonstrated that CABG was associated with decreased repeat revascularizations [14, 17]. In the three-vessel disease population with CKD, patients undergoing PCI showed a higher incidence of repeat revascularization compared with CABG [17].

Complete multivessel PCI would be associated with the reduced need for future CABG, a trend towards better survival [18]. However, completeness of revascularization tends to decrease in the presence of kidney disease. In one study, completeness was achieved in only 42.4% of non-HD kidney disease patients [7]. CABG can provide more complete revascularization. In our data, the PCI group had a lower rate of triple-vessel disease or left main trunk disease. After propensity score matching, coronary lesion distribution was not different between the groups. Given that target vessel numbers were greater in the CABG group, patients with more advanced coronary artery disease were likely to be treated surgically.

It is well recognized that the majority of patients show a transient decline in renal function after surgery. Revascularization may be frequently deferred in patients with severe CKD to avoid precipitating end-stage renal failure. Postoperative deterioration in renal

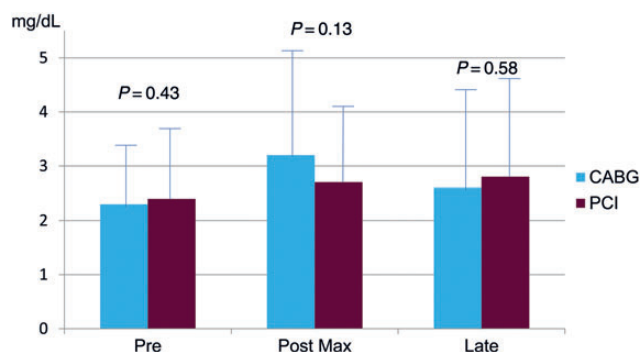


Figure 3: Averaged serum creatinine levels pre-revascularization, during hospitalization (maximum) and at late follow-up for matched CABG and PCI. Error bars show standard deviations. CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention.

Table 3: Event rates (all PCI and CABG)

	One year			Total		
	CABG (n = 77)	PCI (n = 77)	P value	CABG (n = 77)	PCI (n = 77)	P value
MACCEs	13 (17%)	30 (39%)	0.002	25 (32%)	41 (53%)	0.009
AMI	0 (0%)	1 (1%)	0.32	1 (1%)	4 (5%)	0.17
TLR	1 (1%)	8 (10%)	0.02	2 (3%)	12 (16%)	0.005
Any revascularization	3 (4%)	16 (21%)	0.001	5 (6%)	23 (30%)	0.0002
CHF	8 (10%)	14 (18%)	0.17	12 (16%)	22 (29%)	0.05
Stroke	6 (8%)	6 (8%)	1.0	11 (14%)	8 (10%)	0.46
All-cause death	6 (8%)	11 (14%)	0.19	16 (21%)	20 (26%)	0.45
Cardiac death	3 (4%)	8 (10%)	0.12	8 (10%)	13 (17%)	0.24
Sudden death	1 (1%)	3 (4%)	0.31	1 (1%)	4 (5%)	0.17

CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention; MACCEs: major adverse cardiac and cerebrovascular events; AMI: acute myocardial infarction; TLR: target lesion revascularization; CHF: congestive heart failure.

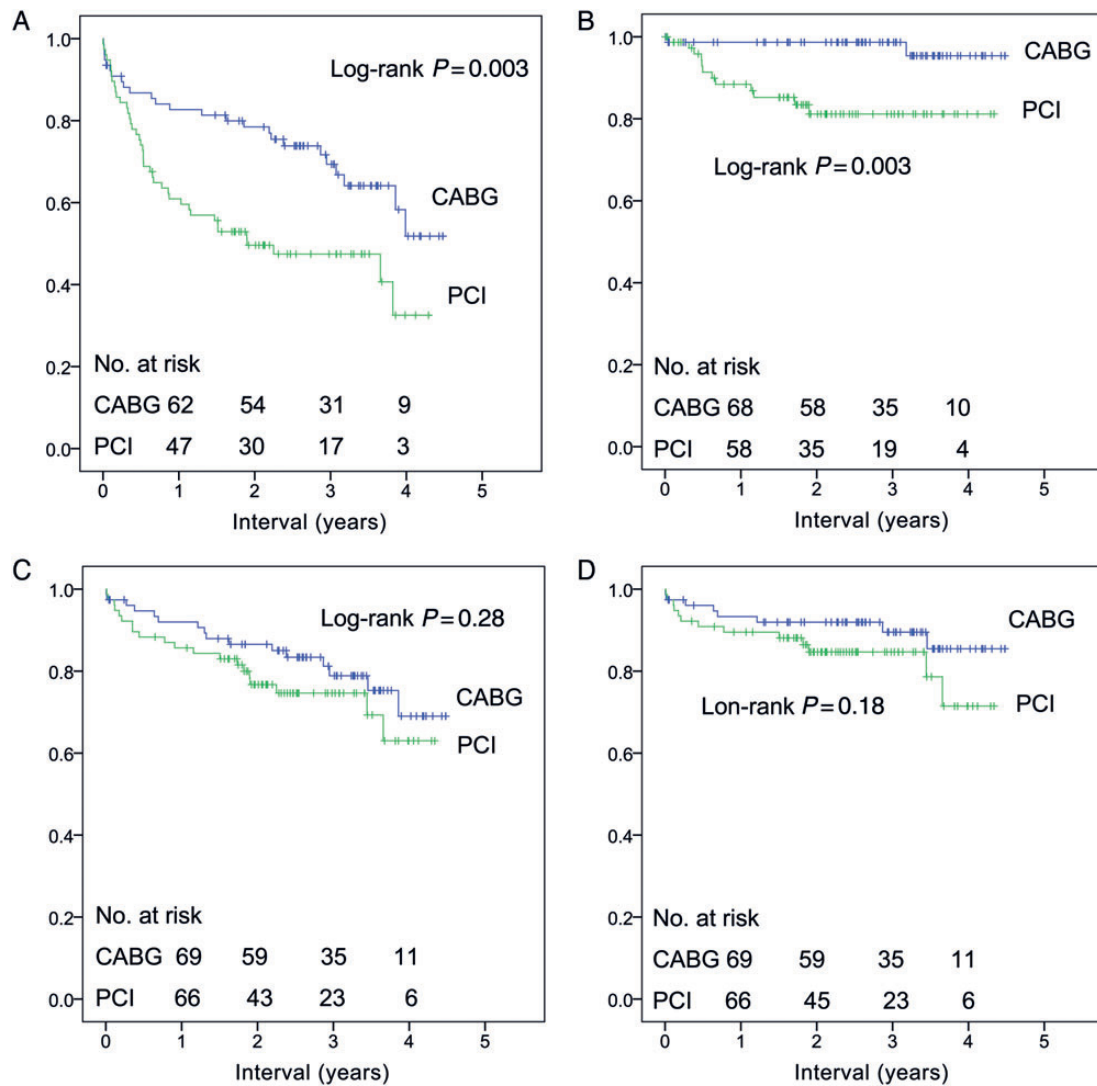


Figure 4: Freedom from (A) major adverse cardiac and cerebrovascular events, (B) target lesion revascularization, (C) all-cause death and (D) cardiac death, comparing matched CABG and PCI groups. CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention.

function is associated with high mortality [19]. The proposed mechanisms for acute kidney injury after cardiac surgery are related to hypotension, volume imbalances, ischaemia, inflammation and haemolysis. As a less invasive alternative, PCI might offer potentially lower procedural risks of death and end-stage renal dysfunction. Ashrith *et al.* demonstrated that CABG patients with moderate or severe CKD had a greater short-term risk of requiring permanent HD after the procedure than PCI patients (4.2 vs 1.5%) [9]. Cooper *et al.* reported that postoperative new requirement for HD was as high as 10.9% for patients with severe renal dysfunction [2]. However, Charytan *et al.* reported that the 3-year cumulative incidence of HD dependence was not different between CABG (6.8%) and PCI (5.4%) for CKD patients, although the risk of HD dependence after CABG was higher during the first 3 months [3]. In the present study, although deterioration in renal function tended to occur more frequently in the CABG group, the new requirement for permanent HD within three months was 9% for PCI and 8% for CABG. Off-pump coronary artery bypass (OPCAB) may reduce the likelihood of acute renal failure in patients with preoperative non-HD renal insufficiency [20], although a previous propensity score analysis revealed that OPCAB did not reduce the risk of

postoperative renal dysfunction in patients with moderate or severe CKD [21]. The potential reasons for perioperative renal dysfunction related to cardiopulmonary bypass might be multifactorial including decreased renal blood flow during hypothermia, non-pulsatile perfusion, haemodilution or haemolysis, inflammation, activation of the complement system and atheroembolism.

Furthermore, OPCAB has been associated with a reduction in postoperative morbidity and mortality, particularly in high-risk patients [22]. A recent study involving 13 085 CABG patients on dialysis from the US Renal Data System database showed that after adjustment for baseline patient characteristics, OPCAB was associated with an 8% reduction in death compared with on-pump CABG [23]. The early survival benefit may be attributed to OPCAB advantages such as the prevention of deleterious inflammatory, vascular and embolic consequences inherent to the cardiopulmonary bypass circuitry. On the contrary, one previous report suggested that OPCAB patients with moderate to severe renal dysfunction had worse long-term survival than on-pump CABG patients [24]. In Japan, OPCAB is the standard treatment for high-risk patients. The 30-day mortality of HD-dependent patients was 2.5% with OPCAB and 4.1% with on-pump CABG [25]. In our

Table 4: Multivariable Cox proportional hazard models for evaluation of the hazards ratio for all-cause death and major adverse cardiac and cerebrovascular events

Variables	HR	95% CI	P value
All-cause death			
PAD	2.71	1.24–5.91	0.01
Prior MI	1.91	0.95–3.84	0.07
Dyslipidaemia	0.55	0.27–1.13	0.10
Age	1.02	0.98–1.07	0.29
CABG	0.74	0.38–1.44	0.37
Cardiac death			
Prior MI	4.04	1.64–9.95	0.002
PAD	3.93	1.43–10.78	0.008
Dyslipidaemia	0.41	0.15–1.14	0.09
CABG	0.56	0.22–1.39	0.21
Age	1.04	0.98–1.10	0.24
MACCEs			
CABG	0.41	0.24–0.68	0.001
Dyslipidaemia	0.50	0.30–0.84	0.009
Stroke	0.43	0.22–0.84	0.01
Malignancy	2.09	1.14–3.85	0.02
PAD	1.80	0.97–3.35	0.06

HR: hazard ratio; CI: confidence interval; PAD: peripheral arterial disease; MI: myocardial infarction; CABG: coronary artery bypass grafting; MACCEs: major adverse cardiac and cerebrovascular events.

study, OPCAB was used in 65% of cases, with an associated in-hospital mortality rate of 2.6%.

Some limitations, which may affect the conclusions drawn from this study, must be noted. Firstly, this is an observational study and its retrospective nature cannot account for the unknown variables affecting the outcomes that are not correlated strongly with the variables used in the risk adjustment. However, retrospective comparisons with propensity score matching are recognized as highly robust and may be widely acceptable. Secondly, a comparison between CABG and PCI is always associated with the difficulty to completely exclude any indication bias, which may affect the results of any observational comparison of outcomes after CABG and PCI. The selection of the revascularization modalities was often dependent on physician or institution. We tried to minimize this effect by computing a propensity score. Still, the mean number of target vessels was significantly different between the two groups. However, after the matching the disease variation was balanced, and the scores for triple-vessel disease and left main trunk disease were not different between the groups. Thirdly, the eGFR was based on a single measurement that may fluctuate, particularly in patients with unstable haemodynamics and changes in medical therapy. Fourthly, innovations in stent devices for coronary intervention are ongoing. Most DESs in this study were first-generation ones; new devices may alter the restenosis rate. Fifthly, this study was based on 26 centres in Japan: there may be significant differences in the indication for pump use and graft selection. The lack of uniformity between study centres is an important limitation.

CONCLUSION

Despite the marked progress in PCI technologies and techniques, CABG remains the standard treatment for patients with coronary artery disease complicated by severe renal dysfunction.

Conflict of interest: none declared.

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