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STATE OF THE ART REVIEWS

Percutaneous coronary intervention compared with coronary artery bypass graft in coronary artery disease patients with chronic kidney disease: a systematic review and meta-analysis

Xin Ren, Wei Liu, Yong Peng, Qiao Li, Hua Chai, Zhen-gang Zhao, Qing-tao Meng, Chi Chen, Chen Zhang, Xiao-lin Luo, Mao Chen, and De-jia Huang

Department of Cardiology, West China Hospital, Sichuan University, Chengdu, China

Abstract

Previous reports of percutaneous coronary intervention versus coronary artery bypass graft outcomes in coronary artery disease patients with chronic kidney disease (CKD) were inconsistent. We evaluated the optimal revascularization strategy for CKD patients. We searched Pub Med, EMBASE, and the Cochrane Central Register of Controlled Trials and scanned the references of relevant articles and reviews. All studies that compared relevant clinical outcomes between percutaneous coronary intervention and coronary artery bypass graft in CKD patients were selected. We defined short-term and long-term all-cause mortality as primary outcome, and long-term incidences of myocardial infarction and revascularization as secondary outcomes. A total of 2235 citations were retrieved, and 31 studies involving 99,054 patients, with 55,383 receiving percutaneous coronary intervention and 43,671 receiving coronary artery bypass graft, were included. In subgroup analyses of dialysis patients receiving percutaneous coronary intervention with stents versus coronary artery bypass graft, CKD patients with multivessel coronary disease, and CKD patients receiving drug-eluting stent versus coronary artery bypass graft, the pooled outcomes revealed that percutaneous coronary intervention possessed lower short-term mortality, but higher late revascularization risk. No significant differences in long-term mortality were observed between the two strategies in these subgroup analyses. In conclusion, in some specific clinical circumstances, CKD patients receiving percutaneous coronary intervention possessed lower short-term all-cause mortality, but higher long-term revascularization risk, than coronary artery bypass graft; long-term all-cause mortality was not different between the two strategies.

Keywords

Chronic kidney disease, coronary artery bypass graft, coronary artery disease, dialysis, percutaneous coronary intervention

History

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Introduction

Ischemic heart disease is the leading contributor to the global burden of disease.[1] Chronic kidney disease (CKD) is considered to be a high-risk factor for coronary artery disease (CAD).[2–4] Approximately, 40–50% patients with severe CKD simultaneously have CAD,[5] some of whom have multivessel coronary disease,[6–8] dialysis dependence,[7,9,10] or other complicated clinical circumstances. These patients have a worse prognosis than non-CKD patients with CAD,[2,3,6–9,11,12] but finding the optimal treatment is a crucial clinical challenge.

Coronary artery bypass graft (CABG) and percutaneous coronary intervention (PCI) are both candidate revascularization strategies for patients with CAD. Both techniques have been improved in the last two decades: CABG has been modified from an on-pump to an off-pump surgery, and PCI has changed from balloon angioplasty to bare-metal stent (BMS) and, later, to drug-eluting stent (DES) implantation. Simultaneously, the debate on which strategy is optimal continues.

A number of randomized controlled trials (RCTs) have compared the efficiencies and benefits of CABG and PCI, but excluded CKD patients or did not reported relevant details.[13–16] A few trials observed and compared the results in CKD patients;[6–9,11,17–21] however, the conclusions were undefined, particularly in some specific circumstances. Therefore, we conducted a meta-analysis, focusing on the different revascularization strategies in CAD patients with CKD, to evaluate which is the optimal choice for these specific populations.

Methods

We considered all types of previous studies that compared the clinical outcomes between PCI and CABG in CAD patients with CKD. We searched Pub Med, EMBASE (both up to 1st week of February 2014), and the Cochrane Central Register of Controlled Trials (up to January 2014), using

Address correspondence to Dr. Mao Chen, Department of Cardiology, West China Hospital, Sichuan University, No. 37 Guoxue Alley, Chengdu, Sichuan 610041, PR China. Tel: +86-028-85423362; Fax: +86-028-85582944; E-mail: hmaochen@vip.sina.com

the following words as MeSH or text words in a combined model: (''chronic kidney disease'' OR ''chronic renal failure'' OR ''chronic renal dysfunction'' OR ''chronic renal insufficient'') AND (''percutaneous coronary intervention'' OR ''percutaneous transluminal coronary angioplasty'' OR ''coronary artery bypass''). No language or date restriction was placed on the literature search. Additionally, we scanned the references of relevant articles and reviews.

Study selection and quality assessment

All citations were assessed for eligibility using the following criteria: (1) all types of studies were considered; (2) patients with CAD and CKD received PCI (balloon angioplasty or stent implantation) or CABG (on-pump or off-pump; arterial graft or venous graft); (3) CKD was defined as the estimated glomerular filtration rate (eGFR)<60 mL/min/1.73 m^2 according to the KDIGO CKD guidelines;[4] and CKD patients with or without dialysis were considered. Studies were excluded for the following reasons: (1) a prior renal transplant had been performed; (2) samples included fewer than 20 patients in total, or less than 10 in either group; (3) no relevant answers regarding our research concerns were provided.

We assessed the methodological quality of the RCTs using the modified Jadad scale. The assessments involved a thorough process of randomization, concealment of allocation, and details of dropouts and withdrawals. The quality assessment of non-RCTs used was the Newcastle-Ottawa scale. The assessed items included: selections (representativeness and definition of cases), comparability (basis of analysis), exposures (ascertainment, detailed description of the methods), and outcomes (assessment, adequate and integral follow-up).

Data extraction

Data were independently extracted by two reviewers, and discrepancies were resolved by a third reviewer. We extracted the following data: type of study, interventions, sample size, gender (male), age, recruited year, follow-up time, duration of dialysis, and short-term and/or long-term outcomes, if available.

Overall analyses and subgroups analyses

All of the included studies compared the clinical outcomes between PCI and CABG in patients with CAD and CKD.

We defined short-term and long-term all-cause mortality as the primary outcome, and long-term incidences of myocardial infarction (MI) and revascularization as secondary outcomes. Some studies combined these outcomes as composite endpoints, but we analyzed them separately. The short-term outcomes were recorded within 30 days after revascularization procedures or within the in-hospital durations. The long-term events were followed-up for at least 1 year.

We performed some subgroups analyses: (1) Dialysis-dependent patients. The CKD patients receiving regular dialysis, hemodialysis, or peritoneal dialysis, at least 1 month before PCI or CABG, were analyzed. We also analyzed the subgroup outcomes of PCI with stent versus CABG in this subgroup. (2) Multivessel coronary disease patients. We performed pool analyses specifically for the studies that enrolled CKD patients with 2 or 3 diseased coronary arteries. (3) DES versus CABG. We analyzed the trials that compared the clinical outcomes of PCI with DES versus CABG in CKD patients.

Statistical analysis

We used the Stata software version 12.0 (StataCorp, College Station, TX) for the analyses. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to compare the outcomes between PCI and CABG. The statistical heterogeneity was quantified by the χ^2 test with p value, and the I^2 statistic. The p value for significance was set at 0.10 for the heterogeneity test. However, the non-significance of heterogeneity does not guarantee good consistency between studies. Therefore, we applied a random effect model (DerSimonian-Laird method). All other p values for significance were set at 0.05, and were 2-tailed.

This meta-analysis was conducted and reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[22] and MOOSE (Meta-analysis of Observational Studies in Epidemiology) statements.[23]

Results

In total, 2235 citations were screened and assessed. After removing duplicates, and screening titles and abstracts, 64 records were assessed in detail. Eight records were excluded as reviews, comments, or letters. We excluded another 24 records for having no relevant answers to our research concerns. We excluded 1 study after full-text review, because we considered it to be of poor quality due to its small sample size ($N = 17$) and considerably high short-term mortality. Finally, 31 studies with accessed full texts were included in the meta-analysis (Figure 1).[6–11,17–21,24–43]

We pooled 99,054 patients in all, of whom 55,383 were treated with PCI, versus 43,671 who were treated with CABG. The patients were recruited from 1977 to 2009. The detailed characteristics and clinical outcomes are shown in Tables 1 and 2.

Overall analyses

Nineteen studies reported the short-term all-cause mortality. The heterogeneity among the studies was considerably high ($I^2 = 69.9\%$, $p < 0.001$). The pooled findings suggested that PCI possessed lower short-term mortality than CABG (OR = 0.51; 95% CI 0.42 to 0.62. All results presented as PCI compared with CABG).

In the 29 studies from which the available data for long-term all-cause mortality were extracted, the heterogeneity was notable ($I^2 = 76.5\%$, $p < 0.001$). The PCI group showed higher long-term all-cause mortality than CABG (OR = 1.12; 95% CI 1.01 to 1.24).

Data for long-term MI events were available from 16 studies, and the heterogeneity was notable ($I^2 = 73.8\%$, $p < 0.001$). The overall outcome revealed that PCI led to higher long-term MI risk than CABG (OR = 1.77; 95% CI 1.44 to 2.17).

There were 18 studies with notable heterogeneity ($I^2 = 73.7\%$, $p < 0.001$) in the pooled analysis of long-term

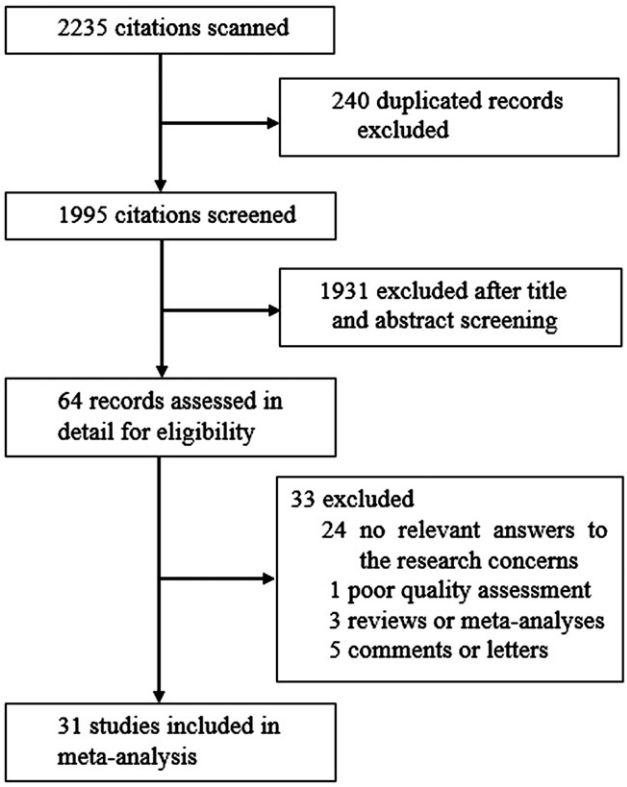

Figure 1. Flow chart of studies selection.

repeat revascularization. The PCI group had a higher revascularization risk compared with the CABG group (OR = 4.87; 95% CI 3.53 to 6.74).

All of the overall analyses showed considerable heterogeneity; therefore, we performed the following subgroup analyses.

Subgroup analyses: dialysis-dependent patients

In total, 23 studies observed the dialysis-dependent patients.[7,9,10,17–19,21,24,27,29,30,32–43]

Short-term all-cause mortality

In the analysis of short-term all-cause mortality in dialysis-dependent patients, the heterogeneity was notable ($I^2 = 65.1\%$, $p < 0.001$). The pooled outcome showed that the risk of short-term all-cause mortality after PCI was significantly lower compared with CABG in dialysis patients (OR = 0.45; 95% CI 0.35 to 0.57). However, for the subgroup of ''Stent versus CABG'' in dialysis patients, three pooled studies showed low heterogeneity ($I^2 = 0.00\%$, $p = 0.625$). The outcome showed an advantage for the PCI group in lower short-term all-cause mortality (OR = 0.39; 95% CI 0.34 to 0.44) (Figure 2A).

Long-term all-cause mortality

We extracted the available data for long-term all-cause mortality from 22 citations for this subgroup analysis. The heterogeneity was considerable ($I^2 = 82.0\%$, $p < 0.001$). The overall outcome did not show a significant difference between the two treatments (OR = 1.09; 95% CI 0.95 to 1.25). In the subgroup of ''Stent versus CABG'', the pooled outcome of 5 studies revealed a similar trend (OR = 1.10; 95% CI 0.86 to 1.43) (Figure 2B).

Secondary outcomes

In the subgroup analysis of long-term MI events in dialysis patients, the heterogeneity was moderate among 11 studies ($I^2 = 37.7\%$, $p = 0.098$). Dialysis patients in the PCI group had higher long-term MI risk than those in the CABG group (OR = 1.70; 95% CI 1.50 to 1.93) (Figure 2C).

In the 13 studies that provided long-term revascularization data in dialysis-dependent patients, 11 trials showed the superiority of CABG in causing fewer late revascularization events. After the pooled analysis, the overall outcome suggested that the higher late revascularization risk after PCI was considerable (OR = 7.67; 95% CI 4.44 to 13.24). With stents, the subgroup outcome of 3 studies also showed that PCI possessed higher long-term revascularization risk (OR = 4.18; 95% CI 1.91 to 9.18) (Figure 2D).

Subgroup analyses: multivessel coronary disease patients

Seven studies specifically compared the outcomes of the two strategies in multivessel CAD patients with CKD.[6–8,18,20,25,28]

Only one trial[18] provided data for short-term all-cause mortality (OR = 0.48; 95% CI 0.22 to 1.05).

Long-term all-cause mortality

For this subgroup analysis, the heterogeneity of all seven studies was low ($I^2 = 12.0\%$, $p = 0.338$). No significant difference between the two groups was shown after pooled analysis (OR = 0.98; 95% CI 0.89 to 1.07) (Figure 3A).

Secondary outcomes

There was a considerably high level of heterogeneity among the five studies that provided the relevant data for long-term MI events in CKD patients with multivessel coronary disease ($I^2 = 90.6\%$, $p < 0.001$). The pooled outcome did not reveal significant difference in long-term MI incidence between PCI and CABG (OR = 1.54; 95% CI 0.94 to 2.52) (Figure 3B).

Four trials were pooled in the analysis of long-term revascularization in CKD patients with multivessel coronary disease, all of which showed the benefits of CABG over PCI, with mild heterogeneity ($I^2 = 33.9\%$, $p = 0.209$). After pooled analysis, PCI still showed obviously higher long-term revascularization risk than CABG (OR = 3.81; 95% CI 2.72 to 5.33) (Figure 3C).

Subgroup analyses: DES versus CABG

Six studies compared the outcomes between DES and CABG.[9,10,17,18,25,26] Two trials used both DES and BMS, but they specifically reported the details of DES.[10,26]

Short-term all-cause mortality

We pooled three studies that reported the available data for short-term all-cause mortality for this subgroup analysis.

Table 1. Characteristics of the studies included in the meta-analysis.

Study	Study type	Intervention	Recruited year	Follow-up		Sample size	Male	Age	Dialysis duration
				Short-term	Long-term				
Takeshita 1992 (JPN)[43]	Retrospective	PTCA/CABG	1983–1989	In-hospital	Mean of 35 months	15/10	21 in all	57	Mean of 3.7 years
Rinehart 1995 (US)[42]	Retrospective	PTCA/CABG	1977–1991	30 days	Mean of 30.7/19.6 months	24/60	14/46	63.6/62.1	Mean of 31.4/15.8 months
Koyanagi 1996 (JPN)[41]	Retrospective	PTCA/CABG	1984–1992	In-hospital	Mean of 2.4/2.2 years	20/23	16/22	57/55	Mean of 4.2/4.7 years
Simsir 1998 (US)[40]	Retrospective	PTCA/CABG	1992–1996	30 days	Mean of 22/19 months	19/22	10/11	64/64	Mean of 41/26 months
Herzog 1999 (US)[39]	Retrospective	PTCA/CABG	1978–1995	In-hospital	Mean of 1.59/1.88 years	6887/7419	3845/4895	–	–
Ohmoto 1999 (JPN)[38]	Retrospective	PTCA/CABG	1983–1997	In-hospital	Mean of 38.2/51.3 months	92/47	75/37	61/60	Mean of 51/52 months
Agirbasli 2000 (US)[37]	Retrospective	PTCA/CABG	1987–1997	In-hospital	1 year	122/130	78/84	58/60	–
Chertow 2000 (US)[36]	Retrospective	PTCA/CABG	1994–1995	30 days	1 year	46/29	28/21	–	–
Ivens 2001 (GER)[35]	Retrospective	PTCA/CABG	1982–1994	30 days	24 months	40/65	29/54	53/57	Mean of 33/41 months
Szczech 2001 (US)[34]	Retrospective	PTCA/CABG	1993–1995	–	3 years	163/244	264 in all	61.1	–
Baldovinos 2002 (ESP)[33]	Retrospective	PTCA/CABG	1994–1999	30 days	24 months	28/23	–	63	Median of 6 years
Herzog 2002 (US)[32]	Retrospective	PTCA, Stent/CABG	1995–1998	In-hospital	Mean of 18.3, 13.3[a]/17.6 months	9116/6668	4905/4150	–	–
Szczech 2002 (US)[31]	Subgroup of BARI	PTCA/CABG	1988–1991	In-hospital	7 years	45/31	56 in all	64.2	–
Aoki 2003 (JPN)[30]	Retrospective	PTCA, Stent/CABG	1997–2001	In-hospital	Mean of 20/22 months	70/55	51/48	65/60	About 60.3/45 months
Hemmelgarn 2004 (CAN)[21]	Prospective	PCI/CABG	1995–2001	–	1.9-2.1 years	363/372	262/291	–	–
						147/153[c]	109/111	47.6/48.4	–
Aoki 2005 (Allied)[8]	Subgroup of ARTS	Stent/CABG	1997–1998	–	5 years	69/73	44/53	70/71	–
Ix 2005 (Allied)[20]	Subgroup of ARTS	Stent/CABG	1997–1998	–	3 years	151/139	86/78	68/69	–
Charytan 2006 (US)[19]	Cross-section	PCI/CABG	2001	In-hospital	–	1552/952	–	–	–
						322/130[c]	–	–	–
Fujimoto 2007 (JPN)[29]	Retrospective	PCI/CABG	–	In-hospital	5 years	81/64	–	–	–
Lopes 2009 (BRA)[28]	Subgroup of MASS II	PCI/CABG	1995–2000	–	5 years	49/46	–	–	–
Manabe 2009 (JPN)[27]	Retrospective	PTCA, Stent/CABG	2004–2007	In-hospital	Mean of 1.48/1.29 years	18/28	17/23	61.2/63.9	Mean of 6/6.3 years
Na 2009 (KOR)[26d]	Retrospective	DES, BMS/CABG	2003–2006	–	Mean of 11 months	401(312)/101	–	–	–
Wang 2009 (CHN)[25]	Retrospective	DES/CABG	2004–2006	–	2 years	724/345	486/240	About 60.8/58.8	–
Ashrith 2010 (US)[18]	Retrospective	DES/CABG	2003–2006	30 days	About 800 days	517/295	301/178	–	–
						33/54[c]	10/16	–	–
Sunagawa 2010 (JPN)[17]	Retrospective	DES/CABG	2002–2006	30 days	Mean of 24/32 months	75/29	55/25	65.2/62.9	–
Chang 2012 (US)[7]	Retrospective	Stent/CABG	1997–2009	–	Median of 1.7 years	7665/14,136	4323/9005	64.9/63.1	Median of 2.6/2.7 years
Charytan 2012 (US)[11]	Retrospective	PTCA, DES, BMS/CABG	2001–2007	In-hospital	3 years	8620/4547	4838/3028	–	–
Terazawa 2012 (JPN)[9]	Retrospective	DES/CABG	2004–2007	30 days	Mean of 39/34.1 months	67/58	51/45	63.6/65	Mean of 6.9/7.3 years
Yeates 2012 (AUS)[24]	Prospective	PTCA, Stent/CABG	1999–2009	30 days	Median of 24.9 months	31/24	21/14	About 61/60	Median of 11/13 months
Chang 2013 (US)[6]	Retrospective	PCI/CABG	1996–2008	–	Median of 3.8/3.9 years	1458/1458	1009/1009	About 72.6/72.6	–
Shroff 2013 (US)[10d]	Retrospective	DES, BMS/CABG	2004–2009	30 days	Median of 1.6, 0.99[b]/1.63 years	16,855(11,844)/6178	9346(6455)/3847	–	–

Notes: PTCA: percutaneous transluminal coronary angioplasty; CABG: coronary artery bypass graft; PCI: percutaneous coronary intervention; DES: drug-eluting stent; BMS: bare-metal stent. All data are expressed by numbers as PCI/CABG in the table.

[a]Data of PTCA and stent group respectively.

[b]Data of DES and BMS group respectively.

[c]Data of dialysis patients.

[d]Data in the parentheses indicate the numbers of DES subgroup.

Table 2. Clinical outcomes of the studies included in the meta-analysis.

	Short-term outcome	Long-term outcome		
Study	All-cause death	All-cause death	MI	Revascularization
Takeshita 1992 (JPN)[43]	0/2	2/3	–	5/1
Rinehart 1995 (US)[42]	1/2	12/32	5/7	–
Koyanagi 1996 (JPN)[41]	0/0	2/4	2/2	15/3
Simsir 1998 (US)[40]	1/1	6/7	–	9/1
Herzog 1999 (US)[39]	371/930	5289/5453	2210/1536	–
Ohmoto 1999 (JPN)[38]	1/7	35/16	14/6	59/15
Agirbasli 2000 (US)[37]	2/9	28/35	6/4	29/3
Chertow 2000 (US)[36]	8/5	21/9	–	–
Ivens 2001 (GER)[35]	0/3	7/9	4/6	23/2
Szczech 2001 (US)[34]	–	75/92	–	–
Baldovinos 2002 (ESP)[33]	6/3	9/4	10/1	–
Herzog 2002 (US)[32]	485/573	4713/2907	–	–
Szczech 2002 (US)[31]	3/1	–	–	–
Aoki 2003 (JPN)[30]	3/3	19/14	11/2	34/7
Hemmelgarn 2004 (CAN)[21]	–	224/232	–	–
	–[a]	76/93	–	–
Aoki 2005 (Allied)[8]	–	10/9	6/8	20/7
Ix 2005 (Allied)[20]	–	10/9	9/11	38/11
Charytan 2006 (US)[19]	145/121	–	–	–
	22/23[a]	–	–	–
Fujimoto 2007 (JPN)[29]	0/9	27/35	2/1	48/11
Lopes 2009 (BRA)[28]	–	9/10	–	–
Manabe 2009 (JPN)[27]	0/0	3/2	0/0	7/1
Na 2009 (KOR)[26b]	–	35(17)/5	13(5)/5	42(35)/8
Wang 2009 (CHN)[25]	–	34/12	37/13	65/14
Ashrith 2010 (US)[18]	12/14	82/52	–	–
	1/3[a]	13/16	–	–
Sunagawa 2010 (JPN)[17]	3/1	28/6	–	36/2
Chang 2012 (US)[7]	–	5378/10,154	2017/2624	–
Charytan 2012 (US)[11]	336/323	2828/1287	–	–
Terazawa 2012 (JPN)[9]	0/0	21/22	8/1	24/6
Yeates 2012 (AUS)[24]	0/3	12/14	–	3/0
Chang 2013 (US)[6]	–	359/325	323/117	324/84
Shroff 2013 (US)[10b]	566(320)/507	10,449(7388)/3512	–	4650(3404)/773

Notes: MI: myocardial infarction; PCI: percutaneous coronary intervention; CABG: coronary artery bypass graft. All data are expressed by numbers as PCI/CABG in the table.
[a]Data of dialysis patients.
[b]Data in the parentheses indicate the numbers of drug-eluting stent subgroup.

The heterogeneity was low ($I^2 = 14.7\%$, $p = 0.309$). The DES group showed a remarkable benefit in short-term mortality over CABG (OR = 0.34; 95% CI 0.25 to 0.46) (Figure 4A).

Long-term all-cause mortality

For long-term all-cause mortality analysis in this subgroup, the heterogeneity of six studies was mild ($I^2 = 24.4\%$, $p = 0.251$). There was also no significant difference in long-term all-cause mortality between patients who received PCI compared with CABG (OR = 1.16; 95% CI 0.95 to 1.42) (Figure 4B).

Secondary outcomes

Three studies provided the data for long-term MI for this subgroup analysis, and the pooled outcome showed no difference between the two procedures (OR = 1.23; 95% CI 0.30 to 5.04) (Figure 4C).

Five studies were pooled in the analysis of long-term revascularization events between DES and CABG in CKD patients. The heterogeneity was high ($I^2 = 48.9\%$, $p = 0.098$). The DES group had a notably higher incidence of late revascularization compared with CABG (OR = 2.84, 95% CI 1.92 to 4.20) (Figure 4D).

Discussion

In our meta-analysis, which incorporated 31 studies, we pooled the available data to compare the clinical outcomes between PCI and CABG using all-cause mortality, and incidences of long-term MI and revascularization. In the overall analyses, PCI was superior for short-term all-cause mortality in CKD patients, and CABG showed superiority for long-term benefits. All the overall analyses had high heterogeneity, thus, the pooled outcomes had little value. We considered whether different types of intervention procedures and varied clinical circumstances among the studies contributed to the high heterogeneity. Hence, we performed some subgroup analyses, with relevant clinical topics, to explore the sources of this high heterogeneity. In the subgroup of dialysis-dependent patients receiving PCI with stents versus CABG, the subgroups of CKD patients with multivessel coronary disease and CKD patients receiving PCI with DES versus CABG, the pooled studies demonstrated good consistency in some analyses. From the pooled outcomes, PCI still showed

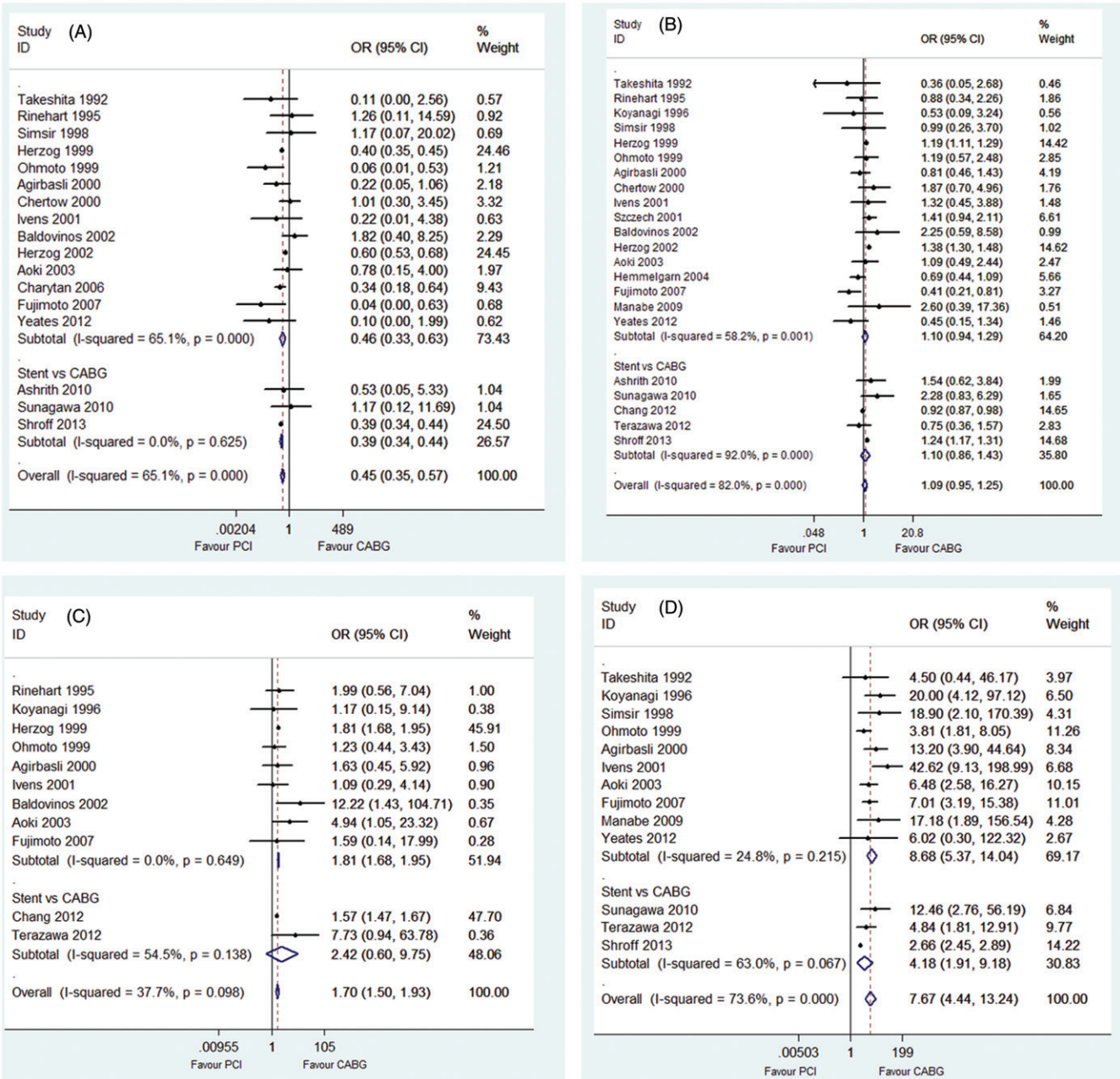

Figure 2. (A) Short-term all-cause mortality in dependent dialysis patients. (B) Long-term all-cause mortality in dependent dialysis patients. (C) Long-term incidence of myocardial infarction in dependent dialysis patients. (D) Long-term incidence of revascularization in dependent dialysis patients.

lower short-term all-cause mortality, but higher late revascularization risk, compared with CABG. However, long-term all-cause mortality was not different between CKD patients who received PCI and CABG.

From the short-term outcome, the superiority of PCI for lower all-cause mortality was observed. This improvement might be mainly ascribed to the high non-cardiac mortality after CABG, especially for CKD patients with complicated clinical circumstances. Potentially fatal non-cardiac complications, such as severe infection, stroke, major bleeding, and respiratory dysfunction,[37,38,44] were more common after CABG than after PCI. All these adverse effects put the CKD patients at higher risk after CABG, although the postoperative complications were reduced by the newer off-pump procedure.[45] Contrast-induced acute kidney injury (AKI)[46] and the bleeding risk associated with multiple anticoagulation and antiplatelet drugs must be considered for PCI. However, due to the lower impact of PCI on other organs or systems, the non-cardiac risk was much lower with PCI than with CABG.

For the specific subgroup analyses, similar to previous reviews,[12,47] our analyses did not reveal an advantage of CABG in lowering long-term all-cause mortality in CKD patients. Several possible reasons explain these findings. (1) In those CKD patients included in these studies, many coexisting factors, such as diabetes mellitus, elderly age, smoking, and peripheral artery disease, could potentially interfere with the final outcomes. (2) In many trials, the risk of death after the revascularization procedure was not proportional during follow-up, and this disproportion was obviously different between PCI and CABG. As shown in some trials, the relative risk of death declined over time, with

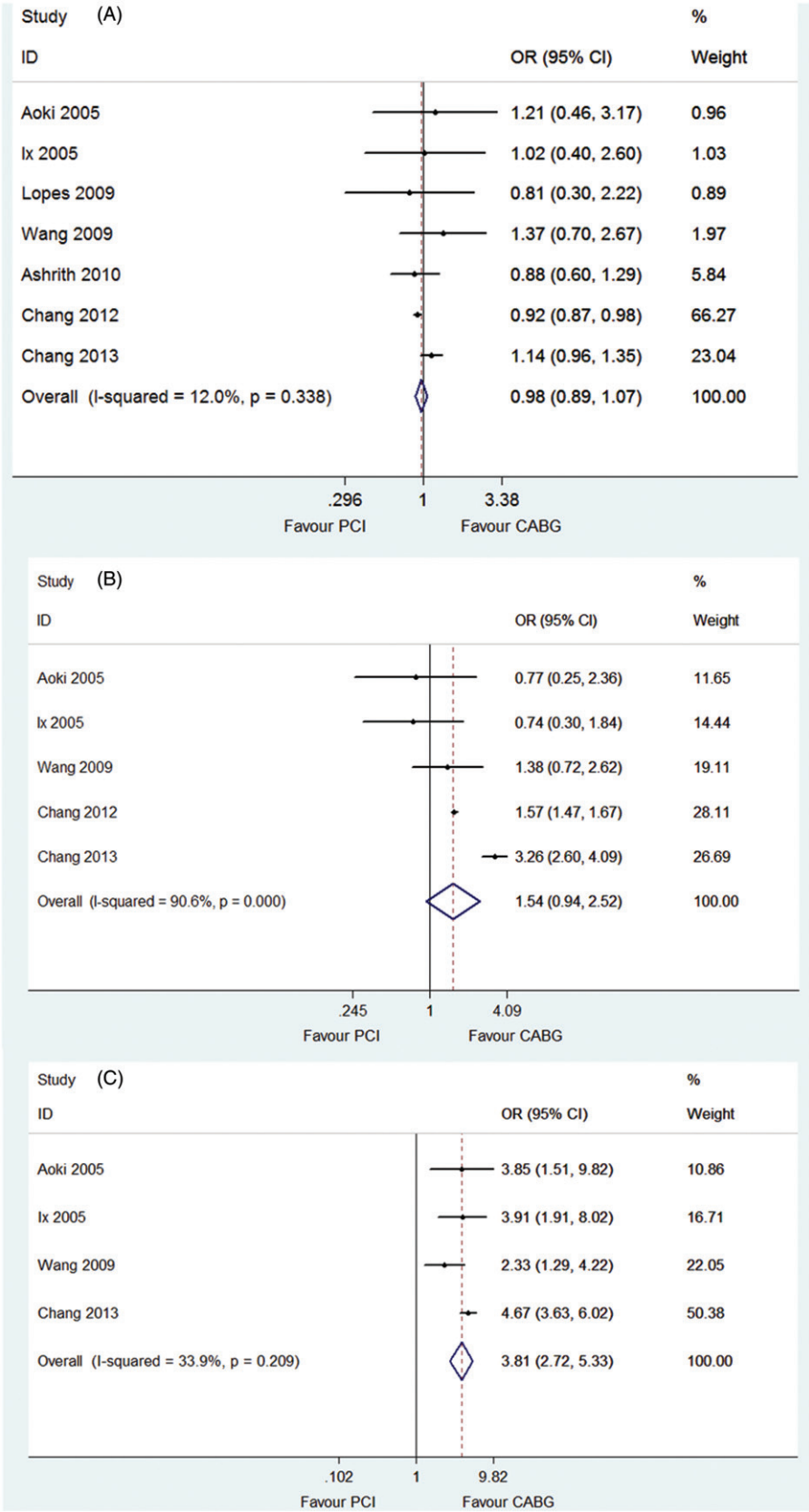

Figure 3. (A) Long-term all-cause mortality in CKD patients with multivessel coronary disease. (B) Long-term incidence of myocardial infarction in CKD patients with multivessel coronary disease. (C) Long-term incidence of revascularization in CKD patients with multivessel coronary disease. CKD: chronic kidney disease.

a higher risk of perioperative death but a greater long-term reduction in death after CABG than after PCI.[11,18] (3) The advantage of CABG over PCI was previously demonstrated in patients with coronary lesions with complex anatomical characteristics, especially left main and 3-vessel coronary disease with moderate and high SYNTAX scores.[16] However, in our multivessel coronary disease subgroup, the trials combined the results of both 2-vessel and 3-vessel diseases, and this combination likely minimized the benefits of CABG in 3-vessel disease patients.[18,25] Therefore, 3-vessel disease

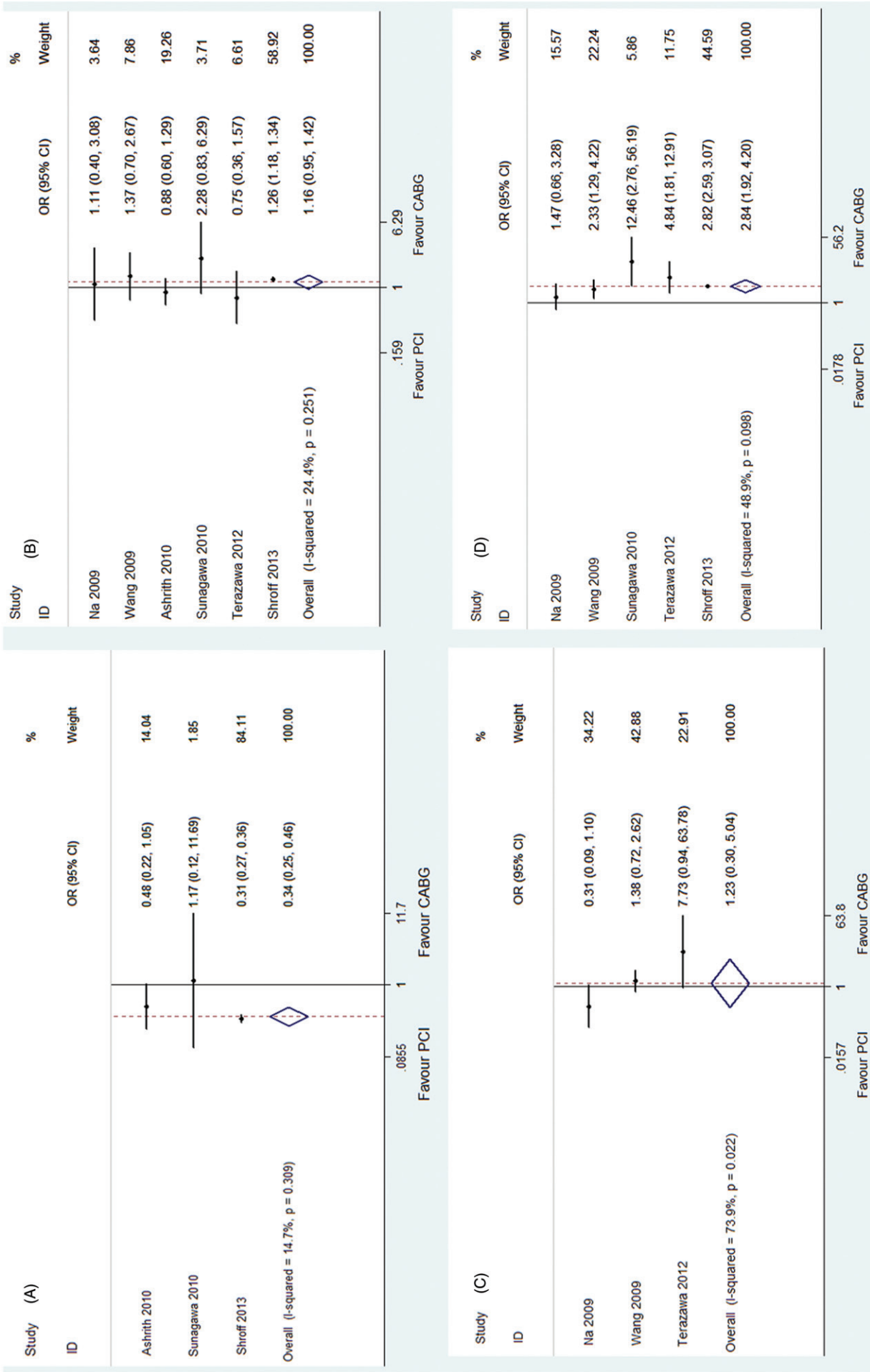

Figure 4. (A) Short-term all-cause mortality in CKD patients comparing PCI with DES versus CABG. (B) Long-term all-cause mortality in CKD patients comparing PCI with DES versus CABG. (C) Long-term incidence of myocardial infarction in CKD patients comparing PCI with DES versus CABG. (D) Long-term incidence of revascularization in CKD patients comparing PCI with DES versus CABG. CKD: chronic kidney disease; PCI: percutaneous coronary intervention; DES: drug-eluting stent; CABG: coronary artery bypass graft.

CKD patients should be analyzed as an individual group. Additionally, whether the SYNTAX score or other anatomical scores are helpful in CKD patients with complex coronary lesions remains unclear.

Although CABG still revealed some benefits during long-term follow-up, especially a markedly lower late repeated revascularization risk, owing to insufficient evidence regarding the benefits on mortality after CABG, we agree with the cautious recommendation of the ACCF/AHA guidelines that CABG might be a reasonable choice for some selected end-stage renal disease patients despite the increased risk of postoperative morbidity and mortality.[48]

Several limitations of the current meta-analysis should be considered. (1) Because no specialized RCTs have focused on this topic to date, we only extracted data from retrospective and prospective studies, cross-sectional studies, and subgroup data from RCTs that compared the clinical outcomes between PCI and CABG. This approach is the major limitation of this meta-analysis. (2) The discrepant clinical circumstances among the included trials could not be ruled out. To control the influence of the confounding factors, adjusted data should be analyzed if possible. However, most of the included studies only reported the non-adjusted data, or data adjusted by different variables. Lacking the primary data, we could not calculate the adjusted outcomes for pooled analyses to preclude the influence of confounding factors. (3) Two of the citations were generated from the ARTS trial,[8,20] and another two trials used the database of the United States Renal Data System;[7,10] although the research concerns, samples, and outcomes were different, some data may overlap. (4) We conducted some subgroup analyses that showed low heterogeneity; however, the heterogeneity tests still demonstrated poor consistencies among the pooled studies in some analyses. Hence, a number of rigorous RCTs will be needed to focus on this topic in the future.

In conclusion, in some specific clinical circumstances, CKD patients receiving PCI had lower short-term all-cause mortality, but higher long-term revascularization risk, than CKD patients undergoing CABG. However, long-term all-cause mortality was not different between the two strategies.

Declaration of interest

No relevant financial interests or any supports exist.

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