

Impact of coronary artery bypass surgery and percutaneous coronary intervention on mortality in patients with chronic kidney disease and on dialysis

A systematic review and meta-analysis

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Abstract

Controversies have been observed among previously published and recently published studies comparing coronary artery bypass surgery (CABG) and percutaneous coronary intervention (PCI) in patients with chronic kidney disease (CKD) and patients on chronic dialysis. This study aimed to show the impact of CABG and PCI on mortality in these patients.

Electronic databases were searched for studies comparing CABG and PCI in patients with CKD. The primary outcome was all-cause death whereas the secondary endpoints included other adverse cardiovascular outcomes reported. Causes of death were also analyzed. Odds ratios (ORs) with 95% confidence intervals (CIs) were used to express the pooled effect on discontinuous variables and the pooled analyses were performed with RevMan 5.3.

Eighteen studies involving a total number of 69,456 patients (29,239 patients in the CABG group and 40,217 patients in the PCI group) were included in this meta-analysis. Short-term mortality insignificantly favored PCI with OR: 1.24, 95% CI: 0.93–1.65; $P=0.15$. Mortality at 1 year was similar in both groups with OR: 0.99, 95% CI: 0.91–1.08; $P=0.86$, whereas the long-term mortality significantly favored CABG in patients with CKD and in patients on chronic dialysis with OR: 0.81, 95% CI: 0.70–0.94; $P=0.007$ and OR: 0.81, 95% CI: 0.69–0.96; $P=0.01$, respectively.

In patients with CKD, the impact of CABG on the short-term mortality was insignificantly higher compared to PCI whereas at 1 year, a similar impact was observed. However, the impact of PCI on mortality was significantly higher during a long-term follow-up period in patients with CKD and in patients on chronic dialysis. Nevertheless, due to a high level of heterogeneity observed among several subgroups analyzed, randomized trials are required to completely solve this issue.

Abbreviations: CABG = coronary artery bypass surgery, CKD = chronic kidney disease, CVDs = cardiovascular diseases, ESRDs = end-stage renal diseases, MAEs = major adverse events, PCI = percutaneous coronary intervention.

Keywords: chronic kidney disease, coronary artery bypass surgery, dialysis, end-stage renal disease, mortality, percutaneous coronary intervention

1. Introduction

Several recently published studies showed a rise in the number of patients suffering from Type 2 diabetes mellitus (T2DM) which could later be complicated by chronic kidney diseases (CKD), thus affecting approximately 13% of the population in

the United States.^[1] Cardiovascular diseases (CVDs) are considered to be responsible for the significant increase in morbidity and mortality among patients suffering from an early or a late stage of CKD.^[2,3] Even in patients with end-stage renal disease (ESRD) undergoing chronic dialysis, CVDs were considered to be responsible for up to 44% of all-cause mortality.^[4]

CKD is expected to rise rapidly in the next decade, but however, the impact of coronary artery bypass surgery (CABG) and percutaneous coronary intervention (PCI) on mortality in patients with CKD and in patients on chronic dialysis is still not very clear. For example, the analysis from a previously published study including patients from CKD cohorts showed CABG to favor patients with long-term mortality compared to PCI.^[5] However, the recently published study by Bangalore et al^[6] showed CABG to be associated with a significantly higher rate of death during a short-term follow-up period, while it was associated with a similar mortality rate in the long term, when compared to PCI. Therefore, in order to solve this issue, we aimed to show the impact of CABG and PCI on mortality in patients with CKD and in patients on chronic dialysis using a large number of patients obtained from CKD cohorts.

Editor: Mistiaen Wilhelm.

The authors have no conflicts of interest to disclose.

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Medicine (2016) 95:27(e4129)

Received: 14 April 2016 / Received in final form: 9 June 2016 / Accepted: 11 June 2016

<http://dx.doi.org/10.1097/MD.0000000000004129>

Table 1**Definitions of chronic kidney diseases reported in the different cohorts involved.**

Study	Definition
Bangalore et al ^[6]	eGFR <60 mL/min/1.73 m ²
Chan et al ^[7]	CrCl <60 mL/min
Chang et al ^[8]	eGFR <60 mL/min/1.73 m ²
Charytan et al ^[9]	Patients with ESRD who were on dialysis initiation or renal transplantation
Hemmelgarn et al ^[10]	Dialysis-dependent kidney disease (on hemodialysis or peritoneal dialysis), nondialysis kidney disease (serum creatinine >2.3 mg/dL [$>200 \mu\text{mol/L}$] but not on dialysis)
Herzog et al ^[11]	Renal replacement therapy for ≥ 90 days and who were on dialysis for ≥ 60 days before revascularization
Khoso et al ^[12]	CrCl ≤ 90 mL/min, consistent with CKD stage 2 of the National Kidney Foundation classification and these patients were classified into 3 CrCl groups: <30 mL/min, 30–59 mL/min and 60–89 mL/min
Lautamäki et al ^[13]	Stage 3b–5 CKD, i.e., eGFR <45 mL/min/1.73 m ²
Lima et al ^[14]	Normal (CrCl: >90 mL/min), mild CKD (60–89 mL/min), and moderate CKD (30–59 mL/min)
Manabe et al ^[15]	Patients on chronic hemodialysis
Marui et al ^[16]	Patients with ESRD and who were on long-term dialysis
Shroff et al ^[17]	Dialysis patients. Eligible patients had received renal replacement therapy for ≥ 90 days before revascularization
Sunagawa et al ^[18]	Chronic renal failure on dialysis
Wang et al ^[19]	eGFR <60 mL/min, consistent with CKD stage 3–5 of the National Kidney Foundation classification
Ashrith et al ^[5]	Estimated glomerular filtration rate of <60 mL/min/1.73 m ²
Aoki et al ^[20]	Patients with ESRD
Baek et al ^[21]	Chronic hemodialysis with duration of ≥ 6 months
Terazawa et al ^[22]	Patients with ESRD and who required dialysis

CKD = chronic kidney disease, CrCl = creatinine clearance, eGFR = estimated glomerular filtrate rate, ESRD = end-stage renal disease.

2. Methods

2.1. Data sources and search strategy

The Cochrane library, PubMed, EMBASE, and Medline databases were searched for studies comparing CABG with PCI in patients with CKD and in patients on chronic dialysis by typing the words or phrases “coronary artery bypass surgery and percutaneous coronary intervention and chronic kidney disease or dialysis.” The abbreviations “CABG, PCI, and CKD” were also used. To further enhance this search, the term “chronic kidney disease” was replaced by the terms “chronic renal disease or chronic kidney injury.” In addition, reference lists of relevant studies were also checked for suitable articles. Only English articles published as from the year 2002 were considered during this search process.

2.2. Inclusion and exclusion criteria

Studies were included if:

- They were observational studies (because all CKD cohorts were observational cohorts).
- They consisted only of patients with CKD (any stage was eligible).
- They compared CABG with PCI.
- They reported mortality and/or other adverse clinical outcomes as their endpoints during any follow-up period.
- They were published as from the year 2002.

Studies were excluded if:

- They were randomized controlled trials (RCTs) involving data from non-CKD cohorts, case studies, or meta-analyses.
- They did not compare CABG with PCI, but instead, reported the outcomes separately, that is, CABG and PCI were not compared, but these studies showed outcomes reported with CABG or PCI separately.
- They did not include patients with CKD or patients on chronic dialysis.

- Mortality was not reported among their clinical endpoints.
- They were published before the year 2002.
- They were duplicates.

2.3. Types of participants

All the participants included in this study were patients at different stages of CKD (early stage of CKD, mild, moderate, or severe CKD), patients with ESRD or even patients on chronic dialysis who underwent revascularization by either CABG or PCI. Different categories of patients with CKD involved are summarized in Table 1.

2.4. Outcomes and follow-up periods

The adverse clinical outcomes included:

- Mortality (all-cause mortality)
- Myocardial infarction (MI)
- Stroke
- Repeated revascularization (involving target vessel revascularization and target lesion revascularization)
- Major adverse events (MAEs) consisting of major adverse cardiac events (MACEs), major adverse cardiovascular, and cerebrovascular events (MACCEs) and composite endpoints which involved death, MI, stroke, and repeated revascularization.

Follow-up periods included:

- In-hospital follow up: mortality reported during the hospital stay.
- Short-term follow up: mortality reported during a period of less than 1 year. In this current meta-analysis, most of the studies had a short-term follow-up period of 1 month.
- Long-term follow up: adverse outcomes reported at or after a period of 1 year.

Table 2 lists the adverse clinical outcomes and corresponding follow up periods of the studies included.

Table 2
Reported outcomes among the included studies.

Study	Reported outcomes	Follow-up period
Bangalore et al ^[6]	Death, MI, stroke, repeated revascularization	1 month, 2.9 years
Chan et al ^[7]	Death, MI, stroke, MACCEs, repeated revascularization	1 month, 1–3 years
Chang et al ^[8]	Death, MI, repeated revascularization	3.9 years
Charytan et al ^[9]	Death	In hospital, 15 months, 3 years
Hemmelgarn et al ^[10]	Death	8 years
Herzog et al ^[11]	Death	In hospital, 1 year, 2 years and 3.5 years
Khoso et al ^[12]	Death, MACCEs, MI, stroke	In hospital
Lautamäki et al ^[13]	Death, MI, stroke, MACCEs, repeated revascularization	1 month, 1 year, 3 years
Lima et al ^[14]	Death, MI	1 month, 1 year, 3 years
Manabe et al ^[15]	Death, MI, MACEs, repeated revascularization	1.5 years
Marui et al ^[16]	Death, stroke, MI, repeated revascularization	1 month, 1 year, 3 years, 5 years
Shroff et al ^[17]	Death	In hospital, 1 month, 1.6 years
Sunagawa et al ^[18]	Death, repeated revascularization, MACEs	In hospital, 2 years
Wang et al ^[19]	Death, MI, CVE, composite endpoint, repeated revascularization	2 years
Ashrith et al ^[5]	Death, MACEs, repeated revascularization	1 month, 2 years
Aoki et al ^[20]	Death, MI, CVE, repeated revascularization, MACEs	In hospital, 1.8 years
Baek et al ^[21]	Death, MACCEs, MI, stroke, repeated revascularization	4 years
Terazawa et al ^[22]	Death, MI, repeated revascularization	1 month, 1 year, 3 years, 5 years

CVEs = cerebrovascular events, MACCEs = major adverse cerebrovascular and cardiovascular events, MACEs = major adverse cardiac events, MI = myocardial infarction.

2.5. Data extraction and review

Two authors (PKB and AB) independently reviewed the data included in this systematic review and meta-analysis. Information regarding author names, year of publications, types of patients involved, total number of patients classified in the CABG and PCI groups respectively, number of patients on chronic dialysis, reported adverse clinical outcomes, causes of mortality among the patients and the follow-up periods were systematically extracted. If the authors disagreed about including certain studies or data, or could not reach a decision whether to accept or reject a study, disagreements were discussed carefully between the authors and a final decision was made. However, if the authors could not reach a consensus, disagreements were resolved by the third author (MHC).

2.6. Methodological quality and statistical analysis

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) was considered for this meta-analysis.^[23] Heterogeneity across the subgroups was carefully assessed using the Cochrane Q-statistic and the I^2 -statistic tests, respectively. For the Q-statistic test, a P -value ≤ 0.05 was considered statistically significant while a P -value greater than 0.05 was considered statistically insignificant. An I^2 value of 0% was considered to be associated with a low level of heterogeneity whereas a larger value of I^2 was associated with an increased heterogeneity. If I^2 was less than 50%, a fixed effect model was used during the statistical analysis and if I^2 was more than 50%, a random effect model was used. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for categorical variables and the pooled analyses were performed with RevMan 5.3 software.

2.7. Ethics approval and patients consent

Ethical approval and patient consents were not indicated for systematic reviews and meta-analyses.

3. Results

3.1. Study selection and the general features of the included studies

A total number of 1618 articles were obtained from electronic databases. A further 17 articles were obtained from the reference lists of highly relevant studies. One thousand six hundred five articles were eliminated since they were either not related to the topic of this research, or they were duplicates. Thirty full-text articles were assessed for eligibility. In the beginning, 5 articles were eliminated because they were meta-analyses and case studies. Another 5 articles were eliminated since they were published before the year 2002. Because non-CKD cohorts including randomized patients were not considered relevant in this study, 2 trials were further eliminated. Finally, 18 studies that satisfied all the inclusion and exclusion criteria of this study were selected. Figure 1 represents the flow diagram for study selection.

A total number of 69,456 patients (40,217 patients involving PCI and 29,239 patients involving CABG) were included in this analysis. The general features of the studies included are listed in Table 3.

The percentage of patients undergoing chronic dialysis, and the types of dialysis involved along with their corresponding duration period are listed in Table 4.

Only 4 studies reported the types of dialysis undergone. Hemodialysis was reported in three studies whereas 1 study included both hemodialysis and peritoneal dialysis. The mean duration of dialysis ranged from 2 to more than 11 years. Further details are listed in Table 4.

3.2. Baseline characteristics

The baseline characteristics of the studies included in this meta-analysis are summarized in Table 5.

According to the baseline features, there were no significant differences between the 2 groups of patients (patients involved in the PCI group and patients involved in the CABG group).

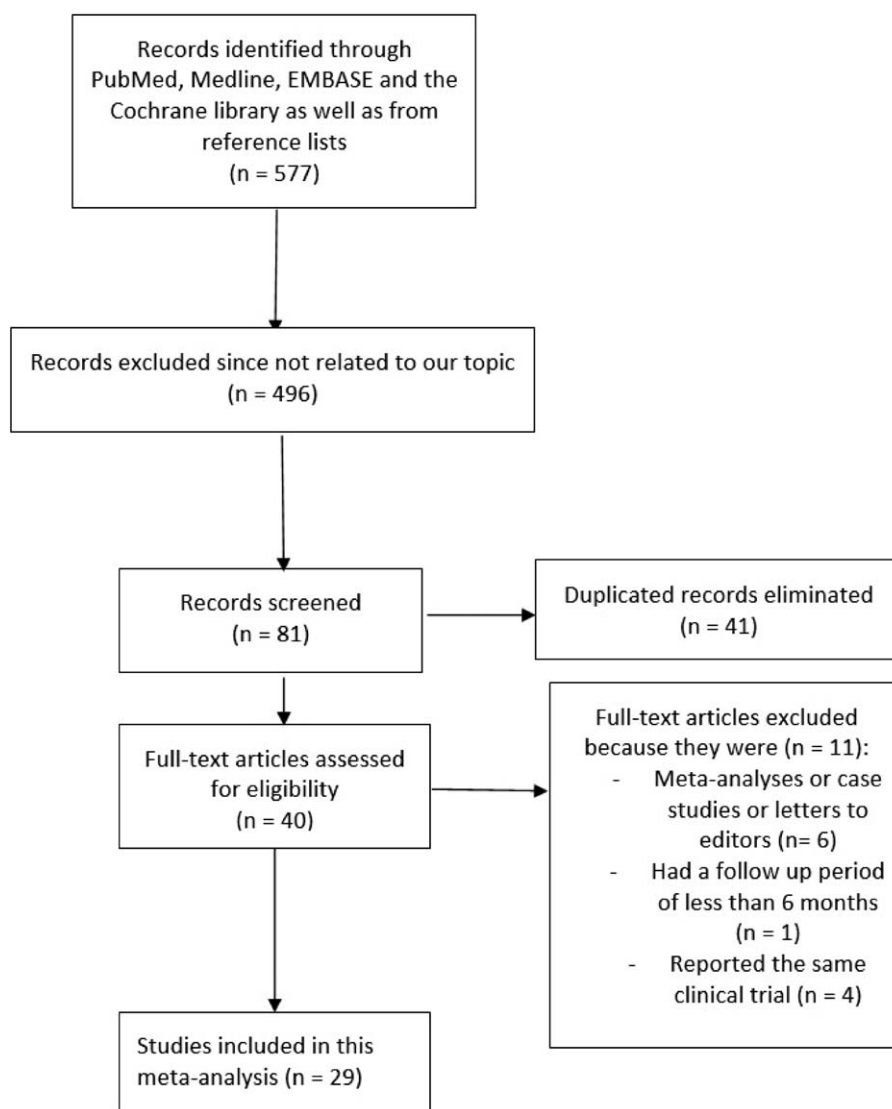


Figure 1. Flow diagram representing the study selection.

Table 3

General features of the included studies.

Study	Type of study	Year of patient enrollment	Type of patients	No. of patients in PCI group (n)	No. of patients in CABG group (n)
Bangalore et al ^[6]	Observational	2008–2011	CKD	2960	2960
Chan et al ^[7]	Retrospective	2008–2011	CKD	996	3010
Chang et al ^[8]	Observational	1996–2008	CKD	4086	4086
Charytan et al ^[9]	Observational	2001–2007	CKD	8620	4547
Hemmelgarn et al ^[10]	Observational	1995–2001	CKD + dialysis	363	372
Herzog et al ^[11]	Retrospective	1995–1998	Dialysis	4280	6668
Khoso et al ^[12]	Cross-sectional	2012–2013	CKD	85	74
Lautamäki et al ^[13]	Retrospective	2007–2010	CKD	110	148
Lima et al ^[14]	Observational	1995–2010	CKD	132	213
Manabe et al ^[15]	Retrospective	2004–2007	Dialysis	18	28
Marui et al ^[16]	Observational	2005–2007	ESRD + dialysis	258	130
Shroff et al ^[17]	Retrospective	2004–2009	Dialysis	16,855	6178
Sunagawa et al ^[18]	Retrospective	2002–2006	Dialysis	75	29
Wang et al ^[19]	Observational	2004–2006	CKD	724	345
Ashrith et al ^[5]	Observational	2003–2006	ESRD	517	295
Aoki et al ^[20]	Observational	1997–2001	ESRD	26	55
Baek et al ^[21]	Observational	2003–2006	Dialysis	44	43
Terazawa et al ^[22]	Observational	2004–2007	Dialysis	67	58
Total no. of patients				40,217	29,239

CABG = coronary artery bypass surgery, CKD = chronic kidney disease, CRF = chronic renal failure, ESRD = end-stage renal disease, PCI = percutaneous coronary intervention, RCT = randomized controlled trials.

Table 4**Percentage of patients undergoing dialysis.**

Study	% in PCI group + duration of dialysis	% in CABG group + duration of dialysis	Types of dialysis
Bangalore et al ^[6]	8.31	8.38	Not mentioned
Chan et al ^[7]	6.4	4.9	Not mentioned
Hemmelgarn et al ^[10]	40.5	41.1	Not mentioned
Herzog et al ^[11]	100	100	Not mentioned
Khoso et al ^[12]	24.7	5.4	Not mentioned
Lautamäki et al ^[13]	11.8	16.2	Not mentioned
Manabe et al ^[15]	100 (6.0 ± 8.0 years)	100 (6.3 ± 8.9 years)	Hemodialysis
Marui et al ^[16]	100	100	Not mentioned
Shroff et al ^[17]	100 (2 to ≥11 years)	100 (2 to ≥11 years)	Peritoneal and hemodialysis
Sunagawa et al ^[18]	100 (5.0 ± 5.0 years)	100 (7.0 ± 4.8 years)	Hemodialysis
Aoki et al ^[20]	100 (49 ± 50 months)	100 (45 ± 50 months)	Not mentioned
Baek et al ^[21]	100 (31 ± 34 months)	100 (24 ± 27 months)	Hemodialysis
Terazawa et al ^[22]	100 (6.9 ± 6.6 years)	100 (7.3 ± 7.0 years)	Not mentioned

CABG=coronary artery bypass surgery, PCI=percutaneous coronary intervention.

3.3. Causes of mortality

All-cause death was considered as the primary endpoint in this analysis. However, the exact causes of death were also reported in certain studies.

Causes of death included:

- Cardiac death
- Death due to respiratory diseases
- Death due to kidney disease/withdrawal from dialysis
- Death due to infection
- Death due to neoplasm
- Other/unknown causes of death

Causes of cardiac death included:

- Death due to heart failure
- Death due to ischemic heart diseases
- Sudden cardiac death
- Valvular heart disease
- Death due to cardiovascular diseases

The causes of death are listed in Table 6.

3.4. Mortality in patients with CKD

In this current analysis, patients with CKD, patients with ESRD and patients on chronic dialysis were separately analyzed for mortality.

During the in-hospital follow-up period, whereby 4621 patients from the CABG group and 8701 patients from the PCI group were analyzed, mortality favored PCI with OR: 1.55, 95% CI: 0.82–2.92; $P=0.17$ (7.16% vs 3.97% in the CABG and PCI group, respectively) in these patients with CKD. However, the result was not statistically significant. This result is shown in Fig. 2.

When the short-term (1 month) mortality was analyzed in these patients with CKD, mortality again insignificantly favored PCI with OR: 1.24, 95% CI: 0.93–1.65; $P=0.15$ among the 10,529 patients analyzed (2.45% vs 1.72%). This result is shown in Fig. 3.

Table 5**Baseline features of the studies included in this meta-analysis.**

Study	M age (y)	Males (%)	HT (%)	Ds (%)	DM (%)	CS (%)
	PCI/CABG	PCI/CABG	PCI/CABG	PCI/CABG	PCI/CABG	PCI/CABG
Bangalore et al ^[6]	69.9/69.6	62.0/61.5	77.0/78.2	62.4/63.3	48.9/48.3	26.4/26.8
Chan et al ^[7]	75.7/73.7	49.7/66.5	83.1/83.5	73.8/78.2	43.0/42.9	48.0/53.6
Chang et al ^[8]	69.1/69.1	71.7/71.7	68.4/69.2	—	36.7/36.6	33.8/33.8
Charytan et al ^{[9],*}	100/100	56.1/66.6	94.9/95.4	—	53.0/56.3	—
Hemmelgarn et al ^{[10],*}	55.5/58.9	72.5/77.4	75.2/80.4	46.0/50.9	41.7/46.2	—
Herzog et al ^{[11],*}	52.0/46.9	54.6/62.2	24.8/25.3	—	46.1/44.7	—
Khoso et al ^[12]	67.0/63.0	74.1/79.7	90.6/90.5	—	70.6/64.9	5.9/17.6
Lautamäki et al ^[13]	73.1/70.7	56.4/58.8	84.5/75.7	—	52.7/44.6	13.6/10.8
Lima et al ^[14]	65.5/64.5	56.7/66.2	78.4/73.9	—	—	8.9/15.5
Manabe et al ^[15]	61.2/63.9	94.4/82.1	77.8/71.4	33.3/21.4	50.0/64.3	33.3/50.0
Marui et al ^[16]	66.2/66.5	73.0/80.0	89.0/82.0	—	65.0/59.0	18.0/15.0
Shroff et al ^{[17],*}	62.5/69.2	56.1/60.8	27.8/26.0	—	75.0/74.0	—
Sunagawa et al ^[18]	65.2/62.9	73.0/87.0	77.0/80.0	20.0/20.0	43.0/43.0	—
Wang et al ^[19]	60.8/58.8	66.8/68.5	59.3/58.9	23.3/23.3	26.7/33.1	45.4/40.3
Ashrith et al ^{[5],*}	56.5/48.5	45.5/48.5	—	71.0/60.0	23.0/23.0	43.0/49.5
Aoki et al ^[20]	64.0/60.0	77.0/87.0	85.0/84.0	35.0/38.0	54.0/53.0	46.0/62.0
Baek et al ^[21]	59.9/63.3	63.6/62.8	90.9/88.4	—	59.1/79.1	6.8/9.3
Terazawa et al ^[22]	63.6/65.0	76.0/78.0	78.0/78.0	—	64.0/52.0	—

CABG=coronary artery bypass surgery, CS=current smoker, DM=diabetes mellitus, Ds=dyslipidemia, HT=hypertension, M=mean, PCI=percutaneous coronary intervention.

* Studies including percentage of patients with age over 65-year old.

Table 6**Causes of mortality in reported studies.**

Causes	Total number of death (n)	Total number of death in PCI group (n)	Total number of death in CABG group (n)	Time period (y)
Marui et al ^[16]	201	134	67	5
Ischemic heart disease	74	49	25	5
Acute MI	11	8	3	5
Heart failure	17	15	2	5
Sudden cardiac death	30	24	6	5
Valvular heart disease	3	3	0	5
Cerebrovascular	19	11	8	5
Respiratory failure	14	12	2	5
Renal failure	13	10	3	5
Infection	9	5	4	5
Gastrointestinal	9	4	5	5
Malignancy	8	4	4	5
Peripheral artery disease	6	3	3	5
Liver failure	4	1	3	5
Trauma	4	3	1	5
Aortic aneurysm	2	1	1	5
Others	51	29	22	5
Shroff et al ^[17]	13,961	10,449	3512	2
Cardiac	7038	5383	1655	2
Cardiovascular	7695	5849	1846	2
Infection	1339	919	420	2
Withdrawal from dialysis	1035	792	243	2
Others/unknown	3892	2889	1003	2
Sunagawa et al ^[18]	34	28	6	2
Sudden death	6	6	0	2
Acute MI	4	3	1	2
VT/VF	2	2	0	2
Heart failure	2	2	0	2
Cerebrovascular	3	2	1	2
Ischemic colitis	2	1	1	2
Sepsis	2	1	1	2
Pneumonia	4	4	0	2
Malignancy	2	2	0	2
Renal failure	1	1	0	2
Suffocation	1	1	0	2
Unknown	5	3	2	2
Manabe et al ^[15]	5	3	2	1.5
Cardiac	3	2	1	1.5
Other	2	1	1	1.5
Aoki et al ^[20]	21	7	14	1.8
MI	1	0	1	1.8
Sudden death	4	2	2	1.8
Infection	5	1	4	1.8
Heart failure	6	2	4	1.8
Terazawa et al ^[22]	43	21	22	3
MI	3	3	0	3
Heart failure	3	2	1	3
Sudden death	11	7	4	3
Infection	12	4	8	3
Respiratory failure	2	0	2	3
Malignancy	3	1	2	3

CABG=coronary artery bypass surgery, MI=myocardial infarction, PCI=percutaneous coronary intervention, VF=ventricular fibrillation, VT=ventricular tachycardia.

Mortality at 1 year was not significantly different between CABG and PCI with OR: 0.99, 95% CI: 0.91–1.08; $P=0.86$ (18.8% vs 19.4%) among the 13,770 patients analyzed. This result is represented in Fig. 3.

Long-term mortality (including a follow-up period of ≥ 1 year) significantly favored CABG with OR: 0.81, 95% CI: 0.70–0.94; $P=0.007$ (18.4% vs 23.8%) among the 15,309 and 17,628 patients with CKD analyzed from the CABG and PCI groups,

respectively. The result showing the long-term mortality is represented in Fig. 2.

When patients with CKD were analyzed for a longer period of time (3 or more years), mortality significantly favored CABG with OR: 0.82, 95% CI: 0.70–0.95; $P=0.01$ (18.8% vs 24.7%) among the 31,868 patients analyzed. This result is illustrated in Fig. 2.

A low level of heterogeneity was observed among the subgroups analyzing short-term and 1-year mortality whereas

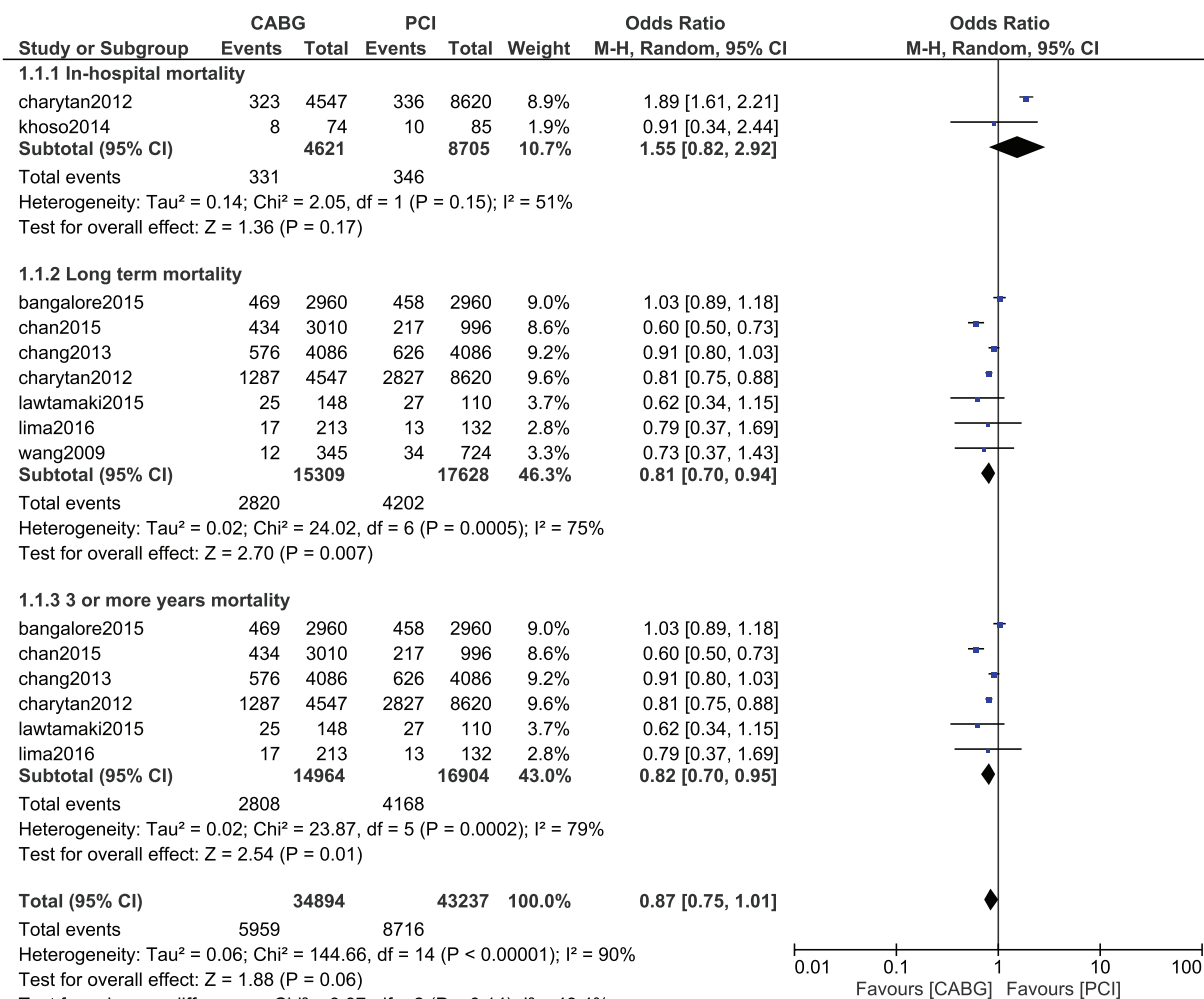


Figure 2. Mortality associated with CABG and PCI in patients with chronic kidney diseases.

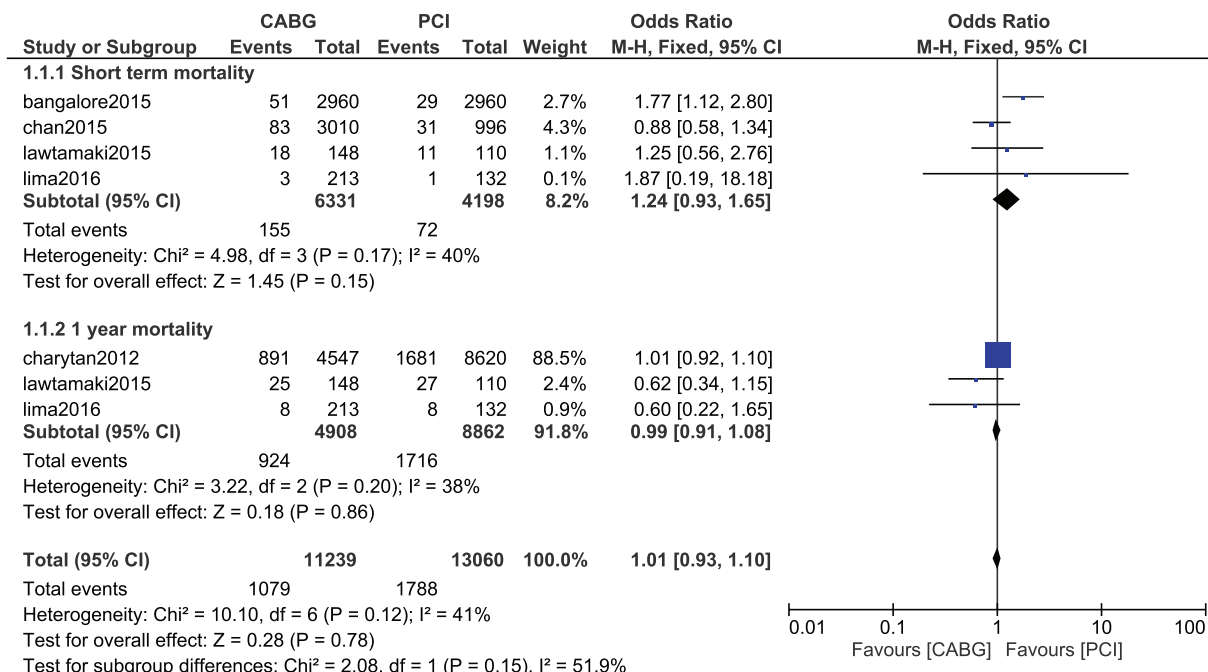


Figure 3. Mortality associated with CABG and PCI in patients with chronic kidney diseases.

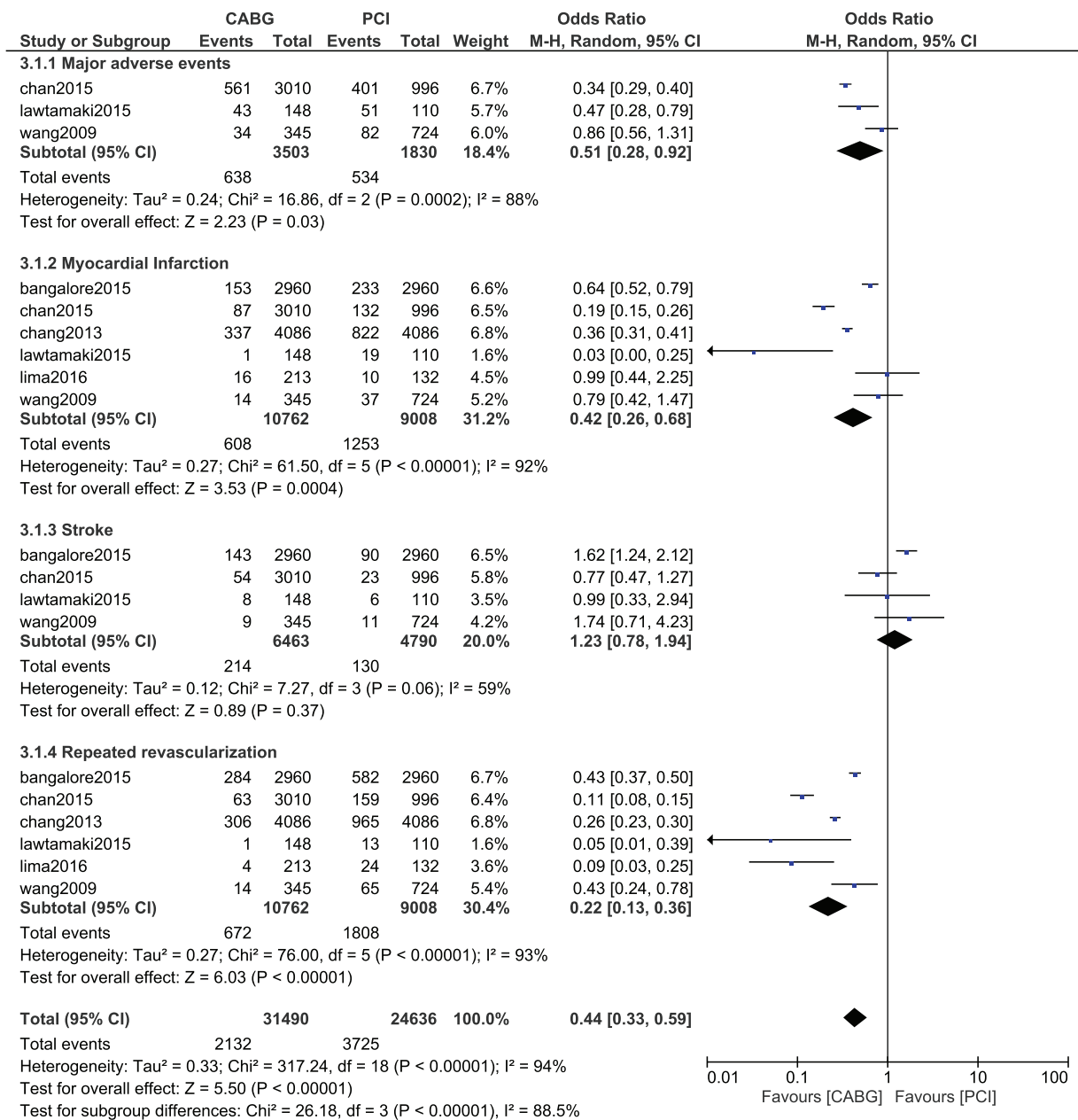


Figure 4. Analysis of the adverse clinical outcomes reported in patients with chronic kidney diseases.

an increased level of heterogeneity was observed among the subgroups analyzing long-term mortality in these patients with CKD.

3.5. Adverse clinical outcomes in patients with CKD

When the other long-term adverse outcomes were analyzed in patients with CKD, MAEs, and MI significantly favored CABG with OR: 0.51, 95% CI: 0.28–0.92; P=0.03 (18.2% vs 29.2%) and OR: 0.42, 95% CI: 0.26–0.68; P=0.0004 (5.65% vs 13.9%), respectively. Stroke favored PCI with OR: 1.23, 95% CI: 0.78–1.94; P=0.37 (3.31% vs 2.71%). However, this result was not statistically significant. Moreover, CABG was associated with a significantly lower rate of repeated revascularization with OR: 0.22, 95% CI: 0.13–0.36; P<0.00001 (6.24% vs 20.1%). However, a high level of heterogeneity. Results showing the long-

term adverse clinical outcomes between CABG and PCI in patients with CKD are represented in Fig. 4.

3.6. Mortality in patients on chronic dialysis

When patients undergoing chronic dialysis were analyzed, long-term mortality significantly favored CABG with OR: 0.81, 95% CI: 0.69–0.96; P=0.01 (57.5% vs 58.8%) among the 34,812 patients analyzed. However, an increased level of heterogeneity was observed in this subgroup of patients (Fig. 5).

3.7. Adverse outcomes in patients on chronic dialysis

Moreover, when the other adverse clinical outcomes were specifically analyzed in patients with chronic dialysis, MI and

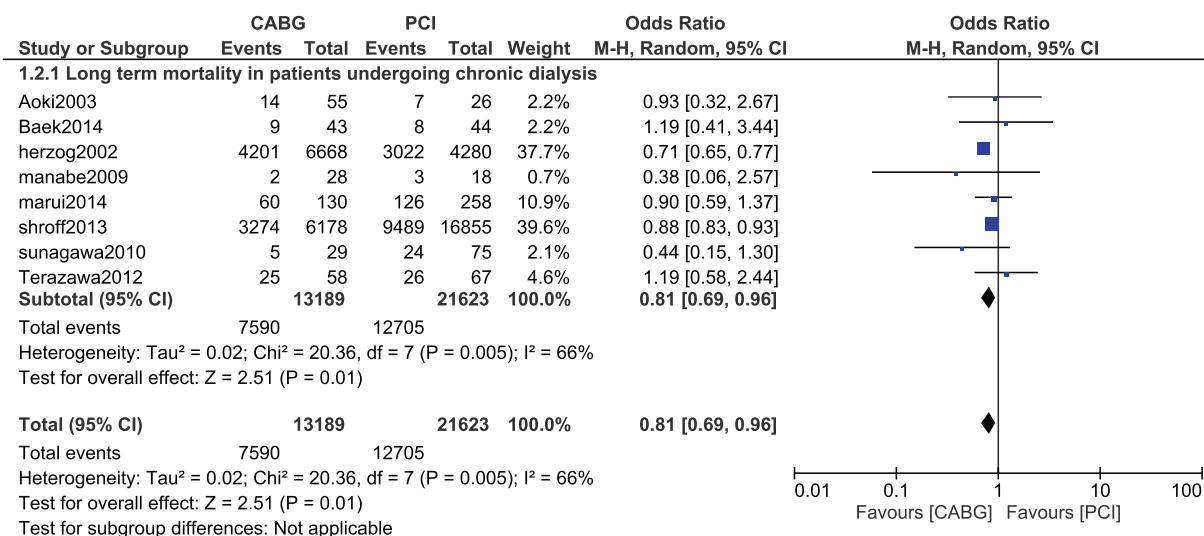


Figure 5. Mortality in patients on chronic dialysis.

repeated revascularization significantly favored CABG with OR: 0.37, 95% CI: 0.18–0.74; P=0.005 (4.54% vs 9.37%) and OR: 0.20, 95% CI: 0.14–0.30; P<0.00001 (8.75% vs 22.8%), respectively. However, even if stroke favored PCI with OR: 1.21,

95% CI: 0.65–2.25; P=0.55 (8.77% vs 8.59%), this result was not statistically significant. A low level of heterogeneity was observed when analyzing the adverse clinical outcomes between CABG and PCI in patients on chronic dialysis (Fig. 6).

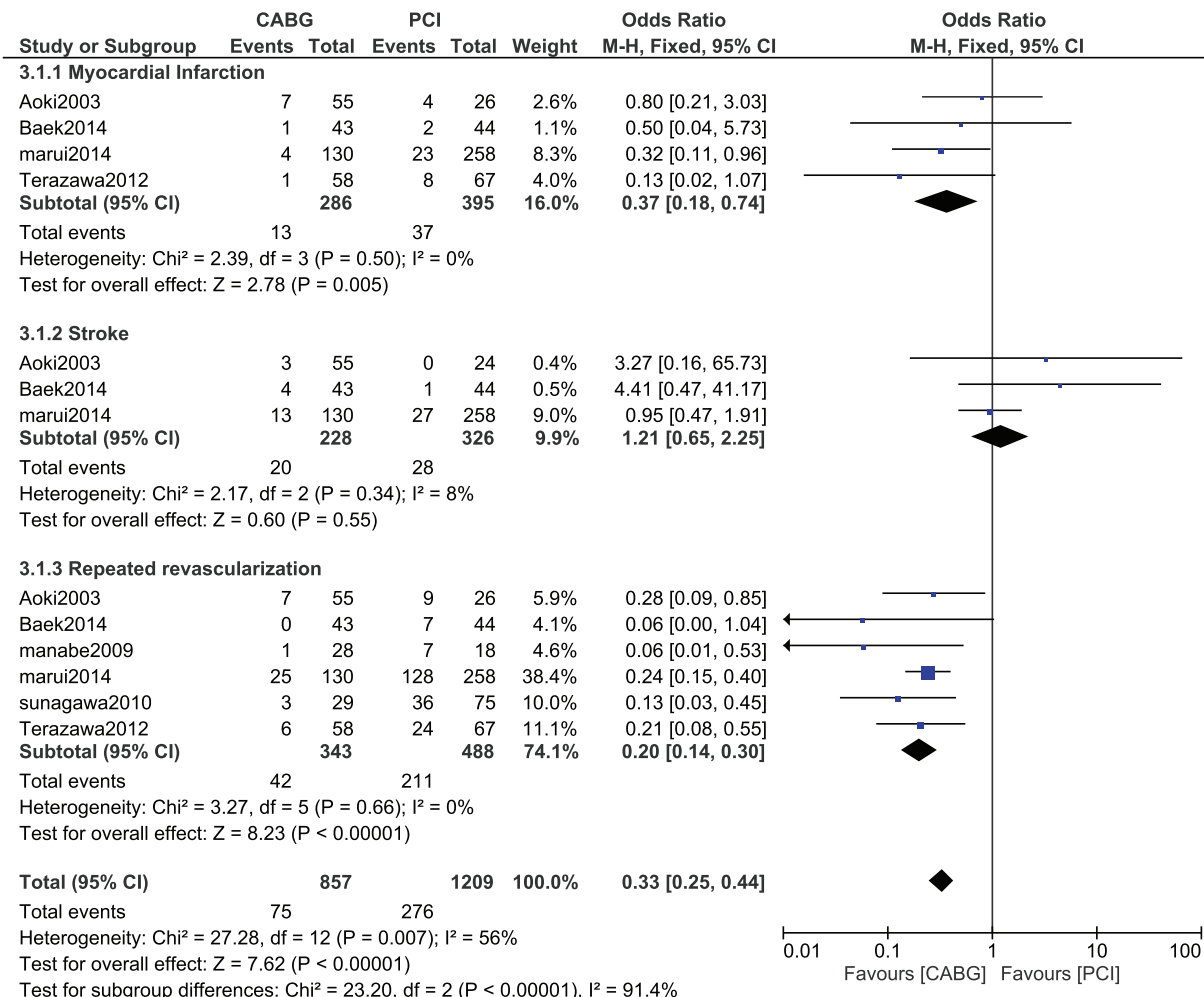


Figure 6. Analysis of the adverse clinical outcomes reported in patients on chronic dialysis.

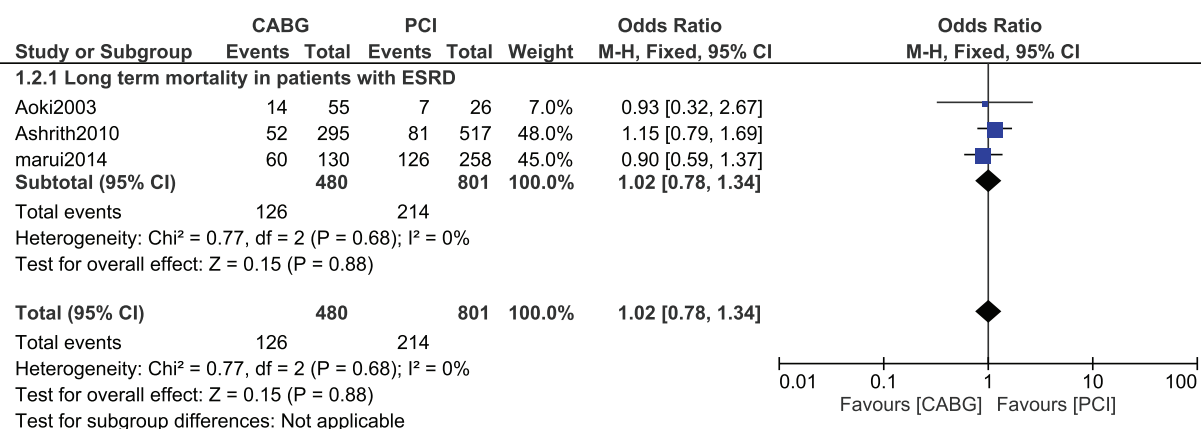


Figure 7. Mortality in patients with end-stage renal diseases.

3.8. Mortality among patients with ESRD

Another subgroup comparing the long-term mortality associated with CABG and PCI in patients with ESRD with or without dialysis showed both revascularization strategies to be associated with a similar mortality rate with OR: 1.02, 95% CI: 0.78–1.34; $P=0.88$ (26.3% vs 26.7%). This result which involved a low level of heterogeneity is represented in Fig. 7.

3.9. Analysis of the causes of mortality

The causes of mortality were also analyzed. Mortality due to cardiac causes was significantly lower in the CABG group with OR: 0.82, 95% CI: 0.76–0.89; $P<0.00001$. Mortality due to renal and heart failure significantly favored CABG with OR: 0.90, 95% CI: 0.78–1.05; $P=0.17$ and OR: 0.41, 95% CI: 0.15–1.09; $P=0.07$, respectively. However, these results were not statistically significant. Moreover, mortality due to infection was significantly higher in the CABG group with OR: 1.42, 95% CI: 1.26–1.60; $P<0.00001$. In addition, other unknown causes of mortality were similar between the CABG and PCI groups with OR: 1.06, 95% CI: 0.97–1.15; $P=0.19$. These results are represented in Fig. 8.

4. Discussion

This study aimed to show the impact of CABG and PCI on mortality in patients with CKD and in patients on chronic dialysis. Results of this current analysis showed that in-hospital and short-term mortality favored PCI in these patients with CKD but these results were not statistically significant. Moreover, CABG and PCI were associated with a similar 1-year mortality rate in these patients with CKD. However, long-term mortality significantly favored CABG. When patients on chronic dialysis were analyzed, the long-term mortality again significantly favored CABG. However, in the subgroup of patients with ESRD, CABG and PCI were associated with a similar rate of long-term mortality.

Reasons contributing to such a result could be related to the fact that higher rates of restenosis and incomplete revascularization were associated with PCI. Another possible mechanism explaining a higher rate of long-term mortality observed among patients who were revascularized by PCI could be the increased risk of contrast induced acute nephropathy which was also associated with a greater risk of adverse clinical events after PCI.

Use of the left internal mammary artery graft in patients who underwent CABG could also be among the reasons why CABG was associated with better outcomes compared to PCI.

The meta-analysis published by Chen et al,^[24] including a total number of 38,740 patients showed that CABG was associated with a higher short-term mortality (OR: 0.55, 95% CI: 0.41–0.73; $P<0.01$) but however, a higher long-term mortality was associated with PCI (OR: 1.29, 95% CI: 1.23–1.35; $P<0.01$). Their results were almost similar to the results of this current study. In addition, the review explaining the management of coronary artery disease in patients with CKD and ESRD suggested that CABG was associated with an increased long-term survival as well as a reduced repeated revascularization when compared to PCI^[25] again supporting the results of this analysis during the long-term follow up. However, in this current study, a similar rate of mortality was observed among patients with CKD at 1-year follow up and in patients with ESRD, respectively. Another study demonstrating the impact of CKD on long-term outcomes showed CABG to be associated with a lower long-term mortality compared to PCI^[14] in a subgroup of patients with T2DM. However, results from this current analysis did not include any separate subgroup of T2DM, but instead, a mixed population of patients with and without T2DM was included.

While assessing the economic attractiveness of coronary artery revascularization in patients with CKD, the author predicted that CABG was an economically attractive alternative compared to PCI or medical therapy for all CKD patients with 2 vessels coronary artery disease.^[26]

Bangalore et al performed a separate propensity score matching specifically on 486 patients who underwent dialysis. Similar to the results of this current study, their results which involved data from registries, also showed CABG to be associated with a significantly lower long-term mortality rate compared to PCI (39.1% vs 54.3% with HR 2.02, 95% CI: 1.40–2.93; $P=0.0002$) in these patients on chronic dialysis.^[6]

Since previously published trials involved data mainly from non-CKD cohorts, the Arterial Revascularization Therapies Study (ARTS) trial showed a similar mortality rate between CABG and PCI in patients with CKD at 3 years (OR: 0.93, 95% CI: 0.54–1.60; $P=0.97$),^[27] and the authors stated that even at 5 years, the rate of death was not statistically significant between these 2 groups (12.3% in the CABG group vs 14.5% in the PCI group)^[28] which was completely different from the results of this current study which included data from CKD

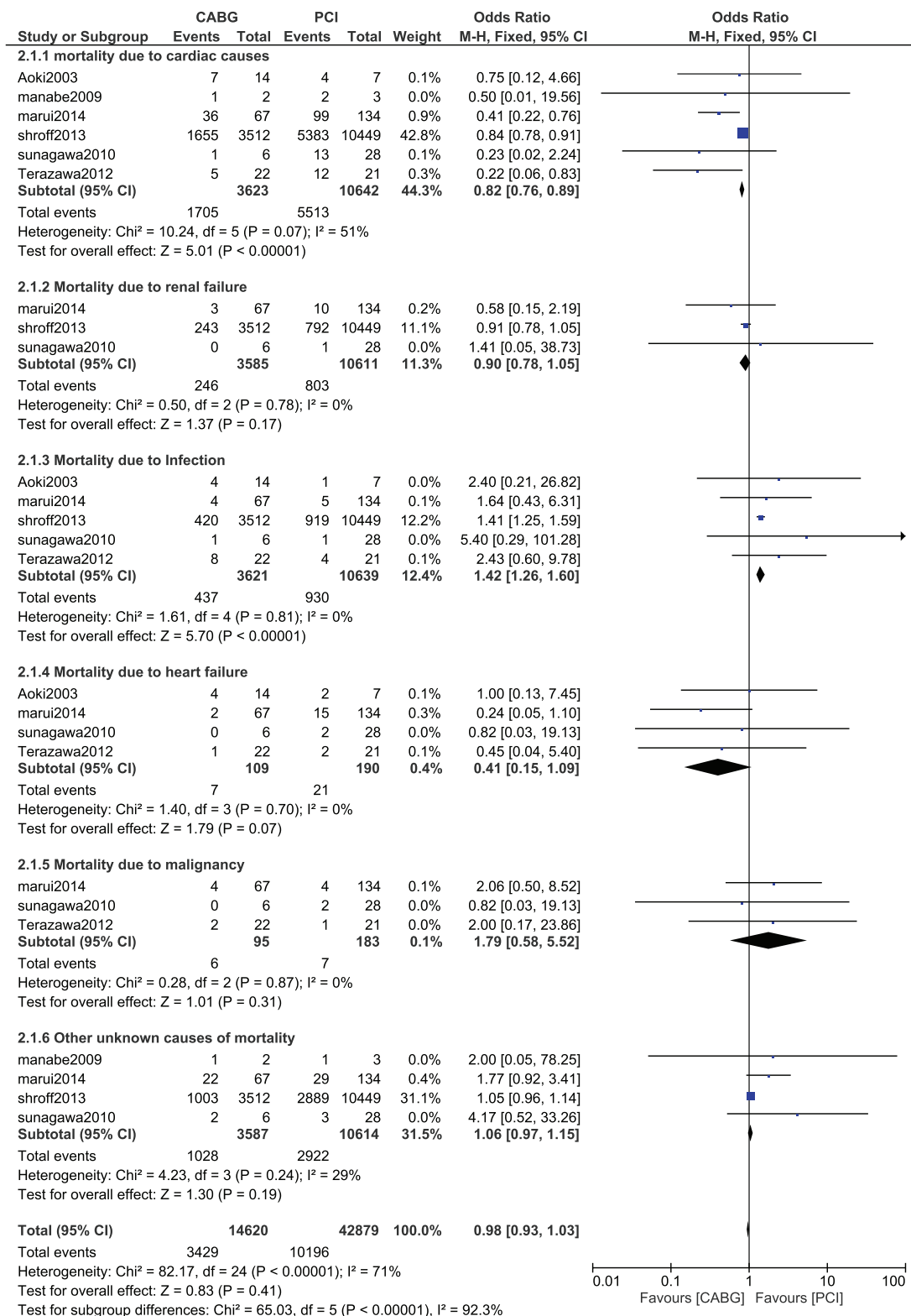


Figure 8. Analysis of the causes of mortality.

cohorts and showed a significantly higher mortality associated with PCI compared to CABG during the long-term follow up (>1 year).

Other studies which reported different results from this current meta-analysis included the clinical update by Cai et al^[29]

reviewing coronary artery disease in patients with CKD. The authors concluded that compared to PCI, CABG was associated with significant perioperative morbidity and mortality. In addition, the study by Wang et al^[19] showed a similar rate of mortality, MI, and cerebrovascular events between CABG and

PCI in patients with CKD. However, their study had several potential limitations which were not identical to this current study. It was a single-study based non-RCT that compared 2 vessel diseases with 3 vessel diseases in patients with CKD.

This current analysis involved patients with mild or moderate CKD, patients with ESRD and patients on chronic dialysis. In the subgroups reporting a similar mortality rate between CABG and PCI, for example, in patients with CKD at 1 year follow up or in patients with ESRD, the SYnergy between PCI with TAXUS™ and Cardiac Surgery (SYNTAX) score could be used to decide which revascularization procedure would be beneficial.^[30] The SYNTAX angiographic grading system has previously been used alone to identify potential risk for revascularization. A higher SYNTAX score is indicative of more complex disease and is hypothesized to represent a bigger therapeutic challenge and associated with a poor prognosis. Hence, representing greatest risk to patients undergoing PCI.

5. Novelty

This study is new in several ways. It is among the first meta-analyses comparing CABG with PCI in patients with CKD, ESRD, and patients on chronic dialysis. Moreover, the different causes of mortality were also compared between CABG and PCI (including different cardiac causes of mortality, mortality due to infection, mortality due to renal failure, mortality due to malignancy, and other unknown causes). Also, long-term adverse clinical outcomes such as MAEs, MI, stroke, and repeated revascularization were also assessed. By representing all these results in 1 study, this study projects a new aspect showing the impact of CABG and PCI on mortality in patients with different stages of CKD and in patients on chronic dialysis.

6. Limitations

Similar to other studies, this study also has several limitations. First of all, due to a limited number of patients, this analysis might not provide robust results. Only patients from observational studies were included. Since data from observational studies are not as good as data from randomized trials, involving data from observational cohorts might not provide great results. However, because there was no randomized cohort comparing CABG and PCI in patients with CKD, we had no other choice than including data only from observational cohorts. Moreover, a high level of heterogeneity was observed among the subgroups analyzing mortality and other adverse outcomes representing a major limitation of this study. This current meta-analysis involved observational studies published in or after the year 2012. Selection bias and publication bias could have contributed to the high level of heterogeneity. In addition, this analysis which involved only articles published in English could be affected by language bias.

7. Conclusion

In patients with CKD, the impact of CABG on the short-term mortality was insignificantly higher compared to PCI whereas at 1 year, a similar impact was observed. However, the impact of PCI on mortality was significantly higher during a long-term follow-up period in patients with CKD and in patients on chronic dialysis. Nevertheless, due to a high level of heterogeneity observed among several subgroups analyzed, randomized trials are required to completely solve this issue.

Acknowledgments

There was no external source of funding for this research and no writing assistance was required.

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