INTRODUCTION

Chronic kidney disease (CKD), also known as chronic renal failure, is described as a continuous decrease in the glomerular filtration rate or abnormalities in kidney structure or function. CKD is an increasingly common disease closely related to the increase in morbidity and mortality of cardiovascular diseases. Whether treated or not, a certain number of patients with CKD progress to the most serious form, which is end-stage renal disease (ESRD). According to the data obtained from the US Kidney Data System, the prevalence

Meta Analysis

Cardiovascular medicine

Coronary revascularisation in patients with chronic kidney disease and end-stage renal disease: A meta-analysis

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Abstract

Objectives: To compare coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) for revascularising coronary arteries in patients with chronic kidney disease (CKD) and end-stage renal disease (ESRD). CKD is described as a continuous decrease in the glomerular filtration rate or abnormalities in kidney structure or function.

Methods: PubMed, Cochrane Library and Embase databases were searched for studies on the revascularisation of coronary arteries in patients with CKD and ESRD.

Results: Since no randomised controlled trials (RCTs) have addressed this issue so far, 31 observational studies involving 74 805 patients were included in this meta-analysis. Compared with PCI, patients undergoing CABG have significantly higher early mortality (CKD: RR = 1.62, 95% CI: 1.17-2.25, heterogeneity = 0.476, I² = 0; ESRD: RR = 1.99, 95% CI: 1.46-2.71, heterogeneity = 0.001, I² = 66.9%). Patients with ESRD undergoing CABG have significantly lower all-cause mortality (RR = 0.95, 95% CI: 0.93-0.96, heterogeneity < 0.001, I² = 82.9%) and cardiac mortality (RR = 0.73, 95% CI: 0.58-0.92, heterogeneity = 0.908, I² = 0). The long-term risk of repeat revascularisation (CKD: RR = 0.24, 95% CI: 0.19-0.30, heterogeneity = 0.489, I² = 0; ESRD: RR = 0.23, 95% CI: 0.15-0.34, heterogeneity = 0.012, I² = 54.4%) and myocardial infarction (CKD: RR = 0.57, 95% CI: 0.38-0.85, heterogeneity = 0.025, I² = 49.9%; ESRD: RR = 0.42, 95% CI: 0.40-0.44, heterogeneity = 0.49, I² = 0) remained significantly higher in the PCI group.

Conclusions: Patients with ESRD, but not CKD, who underwent CABG had significantly lower all-cause mortality and cardiac mortality. However, CABG was associated with an increased risk of early mortality in patients with CKD or ESRD. Adequately powered, contemporary, prospective RCTs are needed to define the optimal revascularisation strategy for patients with CKD and ESRD.
of cardiovascular disease (CVD) in patients with and without CKD (age > 66 years) in 2015 were 66% and 32% respectively. Similarly, the prevalence of coronary heart disease (CAD) is more than twice as high in the CKD population as in the non-CKD population (39% vs 16%). Among patients with ESRD undergoing haemodialysis, the prevalence of CVD and CAD is quite high, estimated at 70% and 42% respectively.

Percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) are conventional methods for improving the symptoms and prognosis of CAD. Patients with CKD undergoing revascularisation surgery have better results than those receiving medication. However, compared with patients with normal renal function, patients with CKD are less likely to undergo this beneficial revascularisation, owing to concerns about further deterioration of renal function after PCI or CABG vascular reconstruction. Several retrospective observational studies have compared outcomes following CABG and PCI in patients with CKD. The results of previous studies were mixed, but the sample size of these studies was relatively small, leading to limited statistical power. Hence, eligible studies were identified, and a detailed analysis on CKD and ESRD was conducted. The present meta-analysis investigated and assessed the effects of CABG and PCI in patients with CKD or ESRD.

2 | MATERIALS AND METHODS

2.1 | Search strategy

PubMed, Embase and the Cochrane library (all up to June 2020) were searched according to the guidelines of the Cochrane Handbook, without language restrictions. The following subject headings and keywords were used: “chronic kidney disease,” “end stage renal disease,” “percutaneous coronary intervention” and “coronary artery bypass grafting.” A supplementary search of the reference lists from all retrieved trials and reviews was also performed. All results were imported into Endnote X9 (Thomson Reuters, NY, USA) for the exclusion of duplicates, following which the titles, abstracts and full texts of eligible trials were screened.

2.2 | Selection criteria

The inclusion criteria were as follows: (1) a retrospective study or randomised controlled trial, (2) patients with CKD or ESRD, (3) CABG and PCI as treatment methods and (4) a minimum follow-up of 6 months. CKD was defined as estimated glomerular filtration (eGFR) < 60 mL/ min/1.73 m². ESRD was defined as any kidney disease requiring long-term haemodialysis or peritoneal dialysis. The exclusion criteria were as follows: (1) the inclusion criteria not fulfilled, and (2) studies on the same population or overlapping database.

2.3 | Data extraction and quality assessment

The available data were extracted from each study by two investigators independently, according to the aforementioned inclusion criteria; any disagreement was subsequently resolved by a discussion with a third author. The following data were collected from each study: first author’s name, publication year, a country where the study was performed, number of patients, sex of patients, mean age of patients, time of follow-up, study design and outcomes. The improved Newcastle-Ottawa scale (NOS) was used to evaluate the quality of the studies. This scale has 3 sections, including election (4 items), comparability (2 items) and exposure or outcomes (3 items), ranging from 0 to 9. Two researchers independently assessed the quality of the study, and the scores were considered as low quality (<7 points) and high quality (≥7 points).

2.4 | Statistical analysis

The pooled risk ratios (RRs) and 95% confidence intervals (CIs) were calculated from eligible studies. The Q statistics and I² were used to assess between-study heterogeneity with a P value of <.1 in the Q test and I² of ≥50% indicating significant heterogeneity. A preliminary analysis was conducted using a fixed-effects model (Mantel-Haenszel method); in the case of high heterogeneity, a random-effects model was employed (Der Simonian and Laird). The relative influence of each study on the pooled estimate was assessed by excluding each study sequentially for sensitivity analysis. The publication bias was assessed using the funnel plot as well as Beggs’s and Egger’s tests. All statistical analyses were performed at a significance level of .05 using Stata software version 13 (Stata Corp, TX, USA).

What’s known
- Chronic kidney disease is an increasingly common disease closely related to the increase in morbidity and mortality of cardiovascular diseases.

What’s new?
- Patients with end-stage renal disease (ESRD) but not chronic kidney disease (CKD), who underwent coronary artery bypass grafting (CABG) had significantly lower all-cause mortality and cardiac mortality. However, CABG was associated with an increased risk of early mortality in patients with CKD or ESRD.
3 | RESULTS

3.1 | Characteristics of the studies

A total of 348 studies were initially identified by searching the database. After removing the duplicates, 236 studies were screened and 58 studies were included in the second phase to assess their eligibility. As a result, 31 studies met these requirements and were included in this analysis. The flow chart of the selection process is presented in Figure 1. The main characteristics of the 31 included studies are presented in Table 1. The final analysis included a total of 74,805 patients, with 37,286 patients in the CABG group and 37,519 patients in the PCI group. Although the literature was searched without any date restriction, all of the studies included in the systematic review and meta-analysis were published between 1995 and 2020. The percentage of men was 50%-95.6% among all participants. The study quality was assessed using the modified version of the NOS for the case-control study. All included studies were considered of high quality because the NOS scores were not less than 7 for each study (Table 2). Table 3 summarising all other meta-analysis papers on this topic.

3.2 | Quantitative synthesis

3.2.1 | Early mortality

Early mortality was reported in seven studies for CKD. Compared with PCI, patients undergoing CABG had significantly higher early mortality.
| Authors/year of publication | Country | Mean age (year) | Men (%) | Type of kidney disease | Type of study | Intervention | Follow-up (month) |
|-----------------------------|---------|----------------|---------|------------------------|--------------|--------------|------------------|
| Rinehart/1995\(^1\)        | USA     | CABG: 62.1 ± 11.1 PCI: 63.6 ± 11.7 | 77/58 | ESRD | Retrospective | CABG 60 PCI 24 | 66 |
| Koyanagi/1996\(^2\)        | Japan   | CABG: 55 ± 8 PCI: 57 ± 10 | 95.6/80 | ESRD | Retrospective | CABG 23 PCI 20 | 60 |
| Simsir/1998\(^3\)          | USA     | CABG: 64 ± 10 PCI: 64 ± 13 | 50/53 | ESRD | Retrospective | CABG 22 PCI 19 | 22 |
| Herzog/1999\(^4\)          | USA     | NA | 66/55.8 | ESRD | Retrospective | CABG 7419 PCI 687 120 |
| Ohmoto/1999\(^5\)          | Japan   | CABG: 60 ± 1 PCI: 61 ± 1 | 81.5/78.7 | ESRD | Retrospective | CABG 47 PCI 92 | 120 |
| Agirbasli/2000[17]         | USA     | CABG: 60 ± 10.6 PCI: 58 ± 13.03 | 65/64 | ESRD | Retrospective | CABG 130 PCI 122 | 12 |
| Chertow/2001\(^6\)         | USA     | NA | 72/61 | ESRD | Retrospective | CABG 29 PCI 46 | 12 |
| Ivens/2001\(^7\)           | Germany | CABG: 57 ± 8 PCI: 53 ± 12 | 83.1/72.5 | ESRD | Retrospective | CABG 65 PCI 40 | 24 |
| Szczech/2001\(^8\)         | USA     | 61.1 ± 11.3 | 64.9 | ESRD | Retrospective | CABG 244 PCI 163 | 36 |
| Herzog/2002\(^9\)          | USA     | NA | 62.2/53.1 | ESRD | Retrospective | CABG 6668 PCI 9116 | 20 |
| Aoki/2003\(^10\)           | Japan   | CABG: 60 ± 9 PCI: 65 ± 9 | 87/69 | ESRD | Retrospective | CABG 55 PCI 70 | 22 |
| Hemmelgarn/2004\(^11\)     | Canada  | NA | 72.6/74.2 | ESRD | Retrospective | CABG 153 PCI 147 | 96 |
| Aoki/2005\(^12\)           | Austria | CABG: 71 ± 6 PCI: 70 ± 6 | 73/64 | CKD | Prospective | CABG 73 PCI 69 | 60 |
| Ix/2005\(^13\)             | Belgium | CABG: 69 ± 7 PCI: 68 ± 6 | 56/57 | CKD | Prospective | CABG 139 PCI 151 | 36 |
| Bae/2007\(^14\)            | Korea   | CABG: 65.6 ± 8.8 PCI: 64 ± 9.8 | 59.6/66.7 | CKD | Retrospective | CABG 52 PCI 48 | 36 |
| Manabe/2009\(^15\)         | Japan   | CABG: 63.9 ± 8.9 PCI: 61.2 ± 12.2 | 82.1/94.4 | ESRD | Retrospective | CABG 28 PCI 18 | 15 |
| Wang/2009\(^16\)           | China   | CABG: 58 ± 10.5 PCI: 60.4 ± 11.3 | 66/67.9 | CKD | Retrospective | CABG 345 PCI 724 | 24 |
| Ashrith/2010\(^17\)        | USA     | NA | 67/60 | CKD, ESRD | Retrospective | CABG 295 PCI 517 | 24 |
| Sunagawa/2010\(^18\)       | Japan   | CABG: 62.9 ± 10.1 PCI: 65.2 ± 12.6 | 87/73 | ESRD | Retrospective | CABG 29 PCI 75 | 32 |
| Chang/2012\(^19\)          | USA     | CABG: 63.1 ± 10.8 PCI: 64.9 ± 12 | 62.9/56.4 | ESRD | Retrospective | CABG 14316 PCI 7665 | 60 |
| Charytan/2012\(^20\)       | USA     | NA | 66.6/56.1 | CKD | Retrospective | CABG 4547 PCI 8620 | 36 |
| Terazawa/2012\(^21\)       | Japan   | CABG: 65 ± 8.2 PCI: 63.6 ± 9.3 | 78/76 | ESRD | Retrospective | CABG 58 PCI 67 | 60 |
| Komiya/2014\(^22\)         | Japan   | CABG: 70.9 ± 8.9 PCI: 74.7 ± 9.4 | 63/58 | CKD | Retrospective | CABG 145 PCI 229 | 48 |
| Marui/2014\(^23\)          | Japan   | CABG: 66.5 ± 8.7 PCI: 66.2 ± 10.6 | 80/73 | ESRD | Retrospective | CABG 130 PCI 258 | 60 |
| Lautamaki/2015\(^24\)      | Finland | CABG: 70.7 ± 9.9 PCI: 73.1 ± 9.9 | 58.8/56.4 | CKD | Retrospective | CABG 148 PCI 110 | 36 |
mortality (RR = 1.62, 95% CI: 1.17-2.25, $P_{\text{heterogeneity}} = .476, I^2 = 0$), which is shown in Figure 2A. Early mortality was reported in 11 studies for ESRD. Compared with PCI, patients with CABG have significantly higher early mortality (RR = 1.99, 95% CI: 1.46-2.71, $P_{\text{heterogeneity}} = .001, I^2 = 66.9$%), which is shown in Figure 2B.

### 3.2.2 | Late mortality

Late mortality was reported in 14 studies for CKD. Late mortality showed no significant difference (RR = 0.86, 95% CI: 0.73-1.01, $P_{\text{heterogeneity}} < .001, I^2 = 70.9$%) between CABG and PCI, which is shown in Figure 2C. Late mortality was reported in 19 studies for ESRD. Compared with PCI, patients undergoing CABG have significantly lower late mortality (RR = 0.95, 95% CI: 0.93-0.96, $P_{\text{heterogeneity}} < .001, I^2 = 82.9$%), which is shown in Figure 2D.

### 3.2.3 | Cardiac mortality

Cardiac mortality was reported in five studies for CKD. Cardiac mortality showed no significant difference (RR = 0.84, 95% CI: 0.56-1.24, $P_{\text{heterogeneity}} = .763, I^2 = 0$) between CABG and PCI, which is shown in Figure 2E. Cardiac mortality was reported in 10 studies for ESRD. Compared with PCI, patients with CABG have significantly lower cardiac mortality (RR = 0.73, 95% CI: 0.58-0.92, $P_{\text{heterogeneity}} = 0.908, I^2 = 0$), which is shown in Figure 2F.

### 3.2.4 | Myocardial infarction

Myocardial infarction was reported in 12 studies for CKD. Compared with PCI, patients with CABG had significantly lower myocardial infarction (RR=0.57, 95%CI:0.38-0.85,$P_{\text{heterogeneity}}=.025,I^2=49.9$%), which is shown in Figure 3A. Myocardial infarction was reported in 11 studies for ESRD. Compared with PCI, patients with CABG have significantly lower myocardial infarction (RR = 0.42, 95% CI: 0.40-0.44, $P_{\text{heterogeneity}} = .49, I^2 = 0$), which is shown in Figure 3B.

### 3.2.5 | Repeat revascularisation

Repeat revascularisation was reported in 11 studies for CKD. Compared with PCI, patients with CABG have significantly lower repeat revascularisation (RR = 0.24, 95% CI: 0.19-0.30, $P_{\text{heterogeneity}} = .489, I^2 = 0$), which is shown in Figure 3C. Repeat revascularisation was reported in 12 studies for ESRD. Compared with PCI, patients with CABG have significantly lower repeat revascularisation (RR = 0.23, 95% CI: 0.15-0.34, $P_{\text{heterogeneity}} = .012, I^2 = 54.4$%), which is shown in Figure 3D.

### 3.2.6 | Stroke incidence

Stroke incidence was reported in 11 studies for CKD. Stroke incidence showed no significant difference (RR = 1.22, 95% CI: 0.94-1.58, $P_{\text{heterogeneity}} = .287, I^2 = 16.5$%) between CABG and PCI, which is shown in Figure 3E. Stroke incidence was reported in seven studies for ESRD. Stroke incidence showed no significant difference (RR = 1.58, 95% CI: 0.99-2.54, $P_{\text{heterogeneity}} = .329, I^2 = 13.3$%) between CABG and PCI, which is shown in Figure 3F.

### 3.3 | Sensitivity analysis

Sensitivity analyses were performed to assess the influence of individual datasets on the pooled estimate by the sequential removal of
TABLE 2  Quality assessment of included studies using the NOS

| Author     | Year | Selection | Comparability | Outcome |
|------------|------|-----------|---------------|---------|
| Rinehart   | 1995 | ★★★      | ★★            | ★★★★    |
| Koyanagi   | 1996 | ★★★      | ★★            | ★★★★    |
| Simsr      | 1998 | ★★★      | ★★            | ★★★★    |
| Herzog     | 1999 | ★★★      | ★★            | ★★★★    |
| Ohmoto     | 1999 | ★★★      | ★★            | ★★★★    |
| Agirbasli  | 2000 | ★★★      | ★★            | ★★★★    |
| Chertow    | 2000 | ★★★      | ★★            | ★★★★    |
| Ivens      | 2001 | ★★★      | ★★            | ★★★★    |
| Szczech    | 2001 | ★★★      | ★★            | ★★★★    |
| Herzog     | 2002 | ★★★      | ★★            | ★★★★    |
| Aoki       | 2003 | ★★★      | ★★            | ★★★★    |
| Hemmelgarn | 2004 | ★★★      | ★★            | ★★★★    |
| Aoki       | 2005 | ★★★      | ★★            | ★★★★    |
| Ix         | 2005 | ★★★      | ★★            | ★★★★    |
| Bae        | 2007 | ★★★      | ★★            | ★★★★    |
| Manabe     | 2009 | ★★★      | ★★            | ★★★★    |
| Wang       | 2009 | ★★★      | ★★            | ★★★★    |
| Ashrith    | 2010 | ★★★      | ★★            | ★★★★    |
| Sunagawa   | 2010 | ★★★      | ★★            | ★★★★    |
| Chang      | 2012 | ★★★      | ★★            | ★★★★    |
| Charytan   | 2012 | ★★★      | ★★            | ★★★★    |
| Terazawa   | 2012 | ★★★      | ★★            | ★★★★    |
| Komiya     | 2014 | ★★★      | ★★            | ★★★★    |
| Marui      | 2014 | ★★★      | ★★            | ★★★★    |
| Lautamaki  | 2015 | ★★★      | ★★            | ★★★★    |
| Pan        | 2016 | ★★★      | ★★            | ★★★★    |
| Kang       | 2017 | ★★★      | ★★            | ★★★★    |
| Giustino   | 2018 | ★★★      | ★★            | ★★★★    |
| Lin        | 2018 | ★★★      | ★★            | ★★★★    |
| Kilic      | 2019 | ★★★      | ★★            | ★★★★    |
| Wang       | 2020 | ★★★      | ★★            | ★★★★    |

Abbreviation: NOS, Newcastle-Ottawa scale.
Studies are assessed using a star rating system based on selection of study subjects (maximum four stars), comparability of study groups (maximum two stars) and assessment of the outcome (maximum three stars). Since no standardized validated criteria exist, studies rated with seven or more stars were considered to be of high quality.

4  | DISCUSSION

Patients with CKD have an increased risk of obstructive coronary heart disease, and patients with ESRD undergoing haemodialysis represent a high-risk group for cardiac ischaemic events. Randomised trials do not provide sufficient evidence to suggest the effectiveness of CABG or PCI compared with drug therapy alone for vascular reconstruction in patients with coronary heart disease. This systematic review and meta-analysis compared CABG and PCI for the revascularisation of coronary arteries in patients with CKD and ESRD. Since no RCTs have addressed this issue so far, 31 related observational studies comprising 74 805 patients were included in the present meta-analysis. Compared with PCI, patients with CKD undergoing CABG have a significantly lower myocardial infarction and repeat revascularisation. No significant difference in overall mortality, cardiac mortality and stroke incidence was observed between CABG and PCI. Compared with PCI, patients with ESRD undergoing CABG have significantly lower overall mortality, cardiac mortality, myocardial infarction and repeat revascularisation. No significant difference was found in stroke incidence between CABG and PCI. However, patients with CKD and undergoing CABG have significantly higher early mortality.

Ten previous meta-analyses summarised in Table 3 investigated the effects of CABG and PCI in patients with CKD or ESRD. However, the optimal revascularisation strategy for patients with ESRD and CKD remains controversial. The present meta-analysis was the largest one to explore the effects of CABG and PCI in patients with CKD and ESRD; it involved 74 805 patients from 31 observational studies. Recently, Kannan et al. conducted a comprehensive meta-analysis to compare CABG versus PCI in patients with ESRD and CKD. Compared with Kannan’s study, more eligible studies were identified for this meta-analysis. Also, the results were different from the previous meta-analysis as a result of the inclusion of additional studies and larger amounts of pooling. Kannan et al found a strong trend for the decreased risk of stroke with PCI compared with CABG in the ESRD group; however, the present analysis showed no significant difference in stroke incidence between CABG and PCI.

Some studies and meta-analyses comparing PCI and CABG for CAD showed that patients with CABG might have a reduced risk of myocardial infarction and revascularisation. However, PCI was found to be superior or similar to CABG in the perioperative risk of stroke. The long-term risk of revascularisation and myocardial infarction was still significantly higher in the PCI group than in the CABG group in the present analysis, which was consistent with previous findings. However, in this meta-analysis, the risk of stroke was comparable between the two groups. In fact, many factors, including calcified ascending aorta and surgical techniques (on-pump or off-pump), might have an impact on the incidence of stroke after CABG. Some studies showed that off-pump CABG reduced the incidence of postoperative stroke by 20%-30% compared with on-pump CABG. These results illustrated the importance of avoiding aortic manipulation, which could minimise the risk of atheromatous plaque embolism, and using a composite artery graft based on the internal mammary artery.
### TABLE 3  Descriptive features of the other meta-analyses in this topic

| Authors        | Country | Year of publication | Numbers of included studies | Numbers of patients | Type of disease | Main discrepancies | Main findings                                                                 |
|----------------|---------|---------------------|----------------------------|--------------------|----------------|--------------------|--------------------------------------------------------------------------------|
| Zheng^42       | China   | 2013                | 16                         | 32 350             | ESRD patients with CAD | Only focusing on ESRD patients | The long-term results of PCI in ESRD patients are dismal, and CABG is significantly superior to PCI in this subset of patients |
| Kannan^43      | USA     | 2016                | 23                         | 49 077             | Patients with CKD and ESRD | Only included 23 studies | There is a strong trend for decreased risk of stroke with PCI when compared with CABG in ESRD and CKD populations |
| Bundhun^44     | China   | 2016                | 18                         | 69 456             | Patients with CKD and on dialysis | Only focusing on patients on dialysis | The impact of CABG on the short-term mortality was insignificantly higher compared to PCI |
| Charytan^45    | USA     | 2016                | 10                         | 3993               | CAD patients with CKD | Only included 10 studies and not focusing on ESRD | CABG significantly reduces the risk of subsequent myocardial infarction and revascularisation without affecting survival in these patients |
| Wang^46        | China   | 2017                | 11                         | 29 246             | MVD patients with CKD | Only included 11 studies and not focusing on ESRD | CABG for patients with CKD and MVD had advantages over PCI-DES in long-term all-cause mortality, MI, repeat revascularisation and MACCE |
| Barbarawi^47   | USA     | 2019                | 5                          | 1212               | LMCAD patients with CKD | Only included 5 studies and not focusing on ESRD | CABG is associated with a lower risk of MACCE, MI and repeat revascularisation; however, it was associated with an increased risk of cerebrovascular accidents when compared with patients who received PCI therapy |
| Wu^46          | China   | 2019                | 17                         | 62 343             | CAD patients with CKD | Only included 17 studies and not focusing on ESRD | PCI for patients with CKD and multivessel disease (multivessel CAD) had advantages over CABG with regard to short-term all-cause death and cerebrovascular accidents |
| Khan^49        | USA     | 2020                | 17                         | 18 599             | LVD                | Not focusing CKD and ESRD | CABG was associated with lower rates of long-term mortality and revascularisation but higher rate of upfront stroke in patients with LVD |
| Garg^50        | USA     | 2020                | 5                          | 4499               | LMCAD              | Not focusing CKD and ESRD | PCI is associated with similar risks of mortality but a higher risk of repeat revascularisation compared with CABG in LMCAD |
| Doulamis^51    | USA     | 2020                | 16                         | 15 313             | CKD                | Only included 16 studies and not focusing on ESRD | In patients with CKD, PCI is associated with higher risk of mortality, MI and repeat revascularisation compared with CABG |
| Qiu^52         | China   | 2021                | 11                         | 4612               | LMCD               | Not focusing CKD and ESRD | The long-term benefit of CABG vs PCI on MACCE in patients with left main coronary disease is consistent across patients with different clinical characteristics |

Abbreviations: CABG, Coronary artery bypass grafting; CAD, coronary artery disease; CKD, chronic kidney disease; ESRD, end-stage renal disease; LMCAD, left main coronary artery disease; LMCD, left main coronary disease; LVD, left ventricular systolic dysfunction; MACCE, major adverse cardiac and cerebrovascular events; MI, myocardial infarction; MVD, multivessel disease; PCI, percutaneous coronary intervention; PCI-DES, percutaneous coronary intervention with drug-eluting stent.
This meta-analysis had several limitations. First, specific randomised, controlled trials related to the topic were lacking. So far, only data from observational studies were extracted, inevitably leading to inherent biases, namely design bias, selection bias, treatment bias and publication bias. Second, these observational studies included patients with CKD having different coronary artery lesions or complications. For example, some studies included patients with multiple coronary artery disease and partial left main disease, some studies included patients with left main disease and other included patients with left main and/or multiple disease. Different degrees of coronary artery complications might have affected the results of this meta-analysis. Third, published event rate summaries were used for each study, rather than individual patient-level data. Therefore, confusion and selection bias could not be ruled out.
out in these studies, and some clinical results were affected by the heterogeneity between a large number of studies. Finally, the specific method of CABG could not be analysed because some studies showed inconsistencies in the results of off-pump and on-pump CABG.

FIGURE 3 Forest plots showing adverse clinical outcomes in patients with CABG or PCI. A, Myocardial infarction in CKD. B, Myocardial infarction in ESRD. C, Repeat revascularisation in CKD. D, Repeat revascularisation in ESRD. E, Stroke incidence in CKD. F, Stroke incidence in ESRD

5 | CONCLUSION

Since no RCTs addressed this issue so far, 31 observational studies involving 74,805 patients were included in this meta-analysis. In conclusion, the long-term risk of repeat revascularisation and
myocardial infarction remained significantly higher in the PCI group than in the CABG group in patients with CKD or ESRD. Compared with patients with PCI, patients with ESRD, but not CKD, who underwent CABG had significantly lower all-cause mortality and cardiovascular mortality. However, CABG was associated with an increased risk of early mortality compared with PCI in patients with CKD or ESRD. Adequately powered, contemporary, prospective RCTs are needed to define the optimal revascularisation strategy for patients with CKD and ESRD.

DISCLOSURES
All authors declare to have no conflict of interest.

ETHICS STATEMENT
This study was designed in compliance with the guidelines of the 2009 Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement. This article is a meta-analysis. The data come from published articles and do not require ethical approval.

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FIGURE 4 Sensitivity analysis examining the influence of individual studies on pooled results. A, Late mortality in CKD. B, Late mortality in ESRD.

FIGURE 5 Funnel plot for publication bias test. A, Late mortality in CKD. B, Late mortality in ESRD. Each point represents a separate study for the indicated association.

DATA AVAILABILITY STATEMENT
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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