IJC Heart & Vasculature 35 (2021) 100813

Contents lists available at ScienceDirect

IJC Heart & Vasculature

journal homepage: www.journals.elsevier.com/ijc-heart-and-vasculature

Does multivessel revascularization fit all patients with STEMI and multivessel coronary artery disease? A systematic review and meta-analysis

Meng-Jin Hu, Xiao-Song Li, Chen Jin, Yue-Jin Yang *

State Key Laboratory of Cardiovascular Disease, Fuwai Hospital, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing 100037, China

ARTICLE INFO

Article history:
Received 2 April 2021
Received in revised form 6 May 2021
Accepted 31 May 2021

Keywords:
Multivessel disease
ST-segment elevation myocardial infarction
Percutaneous coronary intervention
Cardiogenic shock
Chronic total occlusion

ABSTRACT

Objective: We sought to assess the relative merits of different revascularization strategies in patients with ST-segment elevation myocardial infarction (STEMI) and multivessel coronary artery disease complicated by cardiogenic shock or chronic total occlusion (CTO).

Background: Recent randomized trials and *meta*-analysis have suggested that multivessel percutaneous coronary intervention (PCI) is associated with better outcomes in patients with STEMI and multivessel coronary artery disease, however, patients complicated by cardiogenic shock or CTO were excluded.

Methods: Studies that compared multivessel PCI (immediate or staged) with culprit-only PCI in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock or CTO were included. Random odd ratio (OR) and 95% confidence interval (CI) were conducted.

Results: Sixteen studies with 8695 patients complicated by cardiogenic shock and eight studies with 2259 patients complicated by CTO were included. In patients complicated by cardiogenic shock, a strategy of CO-PCI was associated with lower risk for short-term renal failure (OR: 0.75; 95% CI: 0.61–0.93; I^2 = 0.0%), with no significant difference in MACE, all-cause mortality, re-infarction, revascularization, cardiac death, heart failure, major bleeding, or stroke compared with an immediate MV-PCI strategy. In patients complicated by CTO, a strategy of CO-PCI was associated with higher risk for long-term MACE (OR: 2.06; 95% CI: 1.39–3.06; I^2 = 54.0%), all-cause mortality (OR: 2.89; 95% CI: 2.09–4.00; I^2 = 0.0%), cardiac death (OR: 3.12; 95% CI: 2.05–4.75; I^2 = 16.8%), heart failure (OR: 1.99; 95% CI: 1.22–3.24; I^2 = 0.0%), and stroke (OR: 2.80; 95% CI: 1.04–7.53; I^2 = 0.0%) compared with a staged MV-PCI strategy, without any difference in re-infarction, revascularization, or major bleeding.

Conclusions: For patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, an immediate multivessel PCI was not advocated due to a higher risk for short-term renal failure, whereas for patients complicated by CTO, a staged multivessel PCI was advocated due to reduced risks for long-term MACE, all-cause mortality, cardiac death, heart failure, and stroke.

Contents

* Corresponding author at: Department of Cardiology, Fuwai Hospital, 167 Beilishi Road, Beijing 100037, China.
E-mail address: yangyjfw@126.com (Y.-J. Yang).

https://doi.org/10.1016/j.ijcha.2021.100813
2352-9067/

1. Introduction

In patients diagnosed with ST-elevation myocardial infarction (STEMI), it is estimated that approximately 40%–65% patients exhibit multivessel coronary artery disease and are associated with worse short- and long-term mortality and morbidity when compared with subjects with single-vessel disease [1,2]. When it comes to the treatment of multivessel coronary artery disease, three different revascularization strategies are available: 1) culprit-only percutaneous coronary intervention (CO-PCI) strategy in which the only treated vessel was infarct-related artery(IRA); 2) immediate multivessel PCI strategy (MV-PCI) defined as IRA as well as non-IRA were treated during the index procedure; 3) staged MV-PCI strategy in which the IRA was treated at the index procedure followed by a planned PCI of the non-IRA at a later time within one month. Results based on recent randomized trials including PRAMI [3], CvLPRIT [4], DANAMI-3-PRIMULTI [5], COMPARE-ACUTE [6], COMPLETE trials [7] and *meta*-analyses [8,9] have demonstrated that a MV-PCI strategy was superior to a CO-PCI strategy in reducing the risks of revascularization, all-cause death, cardiac death, and myocardial infarction. However, patients with cardiogenic shock or chronic total occlusion (CTO) were excluded from the majority of randomized trials, and the utility and strategy of a MV-PCI strategy in patients with multivessel coronary artery disease complicated by cardiogenic shock or CTO remain unclear. Approximately 5%–10% of patients with STEMI are complicated by cardiogenic shock [10], and multivessel coronary artery disease approaches 80% in patients with STEMI and cardiogenic shock [11]. Meanwhile, CTO in the non-IRA, with the prevalence of 10%–15%, was a more important predictor for one-year mortality than multivessel disease [12,13]. Therefore, considering the great prevalence and significance of cardiogenic shock and CTO in STEMI patients with multivessel coronary artery disease, we sought to investigate the optimal PCI strategy in patients with STEMI and multivessel coronary artery diseases complicated by cardiogenic shock or CTO.

2. Methods

2.1. Data sources

This study was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta- analyses (PRISMA) statement for *meta*-analysis [14]. An electronic search of PubMed, Web of Science, the Cochrane Library, ClinicalTrials.gov, and Google Scholar along with major conference proceedings was conducted using the Medical Subject Heading and the key word search terms "percutaneous coronary intervention (MESH)", "myocardial infarction (MESH)", "cardiogenic shock (MESH)", "PCI", "angiography", "STEMI", "multivessel", "culprit", "non-IRA", "non-infarct", "staged", "immediate", "simultaneous", "incomplete", "complete revascularization", "shock", "chronic total occlusion", and "CTO" from inception through January 2021 with no language restriction. In addition, we searched the presentations at major cardiovascular scientific sessions, the bibliography of original trials, *meta*-analyses, and review articles to find other eligible studies. This *meta*-analysis was registered at the PROSPERO international prospective register of systematic reviews (CRD42020221551).

2.2. Selection criteria and data extraction

We only included observational studies or randomized trials that compared a CO-PCI strategy versus an immediate MV-PCI or staged MV-PCI strategy in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock or CTO. Studies that focused on patients undergoing coronary artery bypass grafting (CABG) were excluded. Two independent authors (Meng-Jin Hu and Xiao-Song Li) extracted information regarding the study period, sample size, study design, definition of cardiogenic shock, CTO and successful PCI, exclusion criteria, primary outcomes, follow-up duration and characteristics of patients enrolled. Any discrepancies were resolved by consensus with third-party adjudication (Chen Jin).

2.3. Outcomes

The primary outcomes for this *meta*-analysis were major adverse cardiac events (MACE), all-cause mortality, re-infarction, and revascularization according to the definition of per individual trial. Secondary outcomes defined as cardiac death, rehospitalization for heart failure, together with safety outcomes defined as major bleeding, renal failure, and stroke were also investigated in the pairwise *meta*-analysis. Subgroups were made based on follow-up time (short-term within 30 days and long-term over 6 months, longest follow-up) in patients complicated by cardiogenic shock.

2.4. Statistical analysis

Raw, unadjusted data from the included studies were extracted. Random-effects models of DerSimonian and Laird were used to construct summary estimate odd ratio (OR) and corresponding 95% confidence interval (CI). Statistical heterogeneity was examined using the I^2 statistic [15] with $I^2 < 25\%$ considered low, 25–75% moderate, and $I^2 > 75\%$ high. Publication bias was assessed by funnel plot [16]. The sensitivity analysis was performed by using a leave-one-out analysis to assess whether the pooled results were influenced by a single trial. All analyses for the pairwise *meta*-

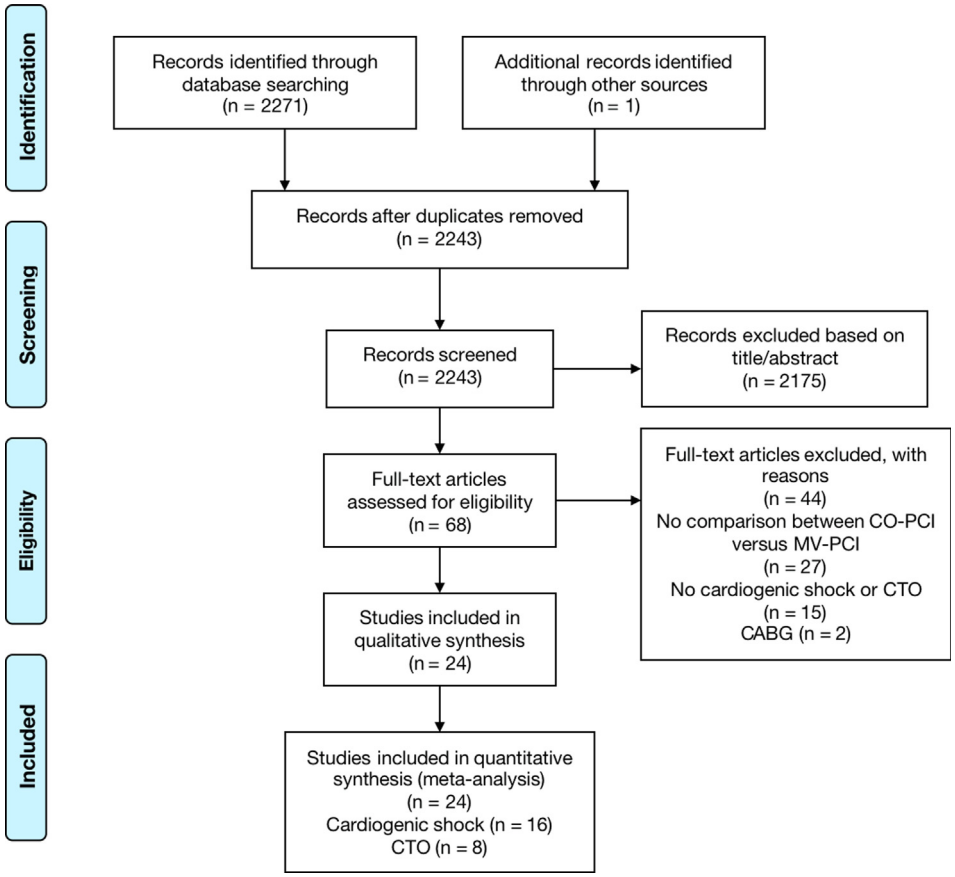

Fig. 1. PRISMA Flow of the Study Search. PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses; MV-PCI: multivessel percutaneous coronary intervention; CO-PCI: culprit-only percutaneous coronary intervention; CTO: chronic total occlusion; CABG: coronary artery bypass grafting.

analysis were performed using STATA software version 14 (STATA Corporation, College Station, Texas).

3. Results

3.1. Study selection and characteristics

Our initial search yielded 2271 articles, of which 68 full-text articles were assessed for eligibility after removing 29 duplicated articles and excluding 2175 irrelevant articles based on titles/abstracts. Forty-four full-text articles were excluded for various reasons (no comparison between CO-PCI and MV-PCI, n = 27; patients without cardiogenic shock or CTO, n = 15; patients received CABG, n = 2) and eventually a total of 24 studies (16 studies focused on cardiogenic shock and 8 studies focused on CTO) were included in the *meta*-analysis according to our eligibility criteria (Fig. 1). Among the 8695 patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, 6436 (74.02%) patients received a CO-PCI strategy, whereas 2259 (25.98%) patients received an immediate MV-PCI strategy. Meanwhile, a CO-PCI strategy was performed in a total of 841 patients with STEMI and multivessel coronary artery disease complicated by CTO, and a staged MV-PCI strategy was performed in a total of 1418 patients. The characteristics of the included studies and patients are shown in Tables 1 and 2. In summary, in patients complicated by cardiogenic shock, ACC-NCDR [17] was the study containing the largest number of patients (3087, 35.50%), CULPRIT-SHOCK [11,18] was the only randomized trial, 13 (81.25%) were multicenter studies. In the majority of studies, multivessel coronary artery disease was defined as stenosis $\geq$ 50% in $\geq$ 2 major epicardial coronary arteries, four studies [12,19–21] also defined a left main (LM) stenosis as two vessel disease. In patients complicated by CTO, all studies were observational studies, four were multicenter studies. Notably, the MV-PCI strategy in patients complicated by cardiogenic shock was performed in an immediate procedure, whereas in patients complicated by CTO, the MV-PCI strategy was performed in a staged manner.

3.2. Outcomes in patients complicated by cardiogenic shock

The results of MACE are detailed in Fig. 2A. During short-term follow-up, a CO-PCI strategy was associated with a lower trend of MACE (OR: 0.81; 95% CI: 0.64–1.04) compared with an immediate MV-PCI strategy. During long-term follow-up, the risk of MACE was similar between a CO-PCI strategy versus an immediate MV-PCI strategy (OR: 0.98; 95% CI: 0.68–1.41; I^2 = 0.0%). All studies reported all-cause mortality during short-term follow-up (in-hospital/within 30 days). However, no significant differences in all-cause mortality were observed between a CO-PCI strategy versus an immediate MV-PCI strategy, either during short-term (OR: 0.92; 95% CI: 0.74–1.13; I^2 = 68.6%) or long-term follow-up (OR: 1.05; 95% CI: 0.80–1.37; I^2 = 77.8%; Fig. 2B). The risk of re-infarction was also similar in patients complicated by cardiogenic shock between a CO-PCI strategy versus an immediate MV-PCI strategy, either during short-term (OR: 1.41; 95% CI: 0.61–3.24; I^2 = 0.0%) or long-term follow-up (OR: 0.88; 95% CI: 0.51–1.51; I^2 = 22.1%; Fig. 2C). The results of revascularization are detailed in Fig. 2D. There were no significant differences between a CO-PCI strategy versus an immediate MV-PCI strategy during short

Table 1
Baseline characteristics of included studies.

First Author Year	Study Period	Sample Size		Study Design	Definition of multivessel coronary artery disease	Definition of cardiogenic shock	Exclusion Criteria	Primary endpoint(s)	Follow-up
		CO-PCI	MV-PCI						
Patients complicated by cardiogenic shock									
Cavender [17] 2009	2004–2007	2654	433	Multicenter, retrospective	CAD in > 1 major artery	SBP < 80 mm Hg and/or CI < 1.8 L/min/m^2 despite maximal treatment or requiring intravenous inotropes and/or an IABP to maintain the SBP at > 80 mm Hg and/or CI > 1.8 L/min/m^2	LM, staged PCI, thrombolytics	All-cause death, stroke, renal failure, bleeding	In-hospital
van der Schaaf [12] 2010	1997–2005	124	37	Single center, retrospective	>50% stenosis in ≥ 1 major non-IRA or LM stenosis ≥ 50%	SBP ≤ 90 mm Hg for ≥ 30 min or vasopressors required to maintain BP > 90 mm Hg, evidence of end organ hypoperfusion (e.g., urine output < 30 mL or cold/diaphoretic extremities or altered mental status), and evidence of elevated filling pressures (e.g., pulmonary congestion on examination or chest x-ray)	NA	All-cause death	1 year
Bauer [22] 2012	2005–2008	254	82	Multicenter, retrospective	≥70% stenosis in ≥ 2 major epicardial vessels	SBP ≤ 90 mm Hg for ≥ 30 min or inotropes needed to maintain SBP > 90 mm Hg and evidence of end-organ hypoperfusion and increased filling pressures	Prior GABG, LM disease	All-cause death	In-hospital
Cavender [23] 2013	2002–2010	32	32	Single center, retrospective, propensity matched	≥50% stenosis in ≥ 2 major epicardial vessels	Sustained episode of SBP < 90 mm Hg, and/or CI < 2.2 L/min/m^2, and/or parenteral inotropic or vasopressor agents or mechanical support needed to maintain SBP and CI above those specified levels	Definite indications for surgery such as significant valvular heart disease, mechanical complications of MI	All-cause death	5 years
Mylotte [21] 2013	1998–2010	103	66	Multicenter, prospective	Stenosis ≥ 70% in a major (≥2.5 mm) non-IRA, distal LM lesion with significant stenosis of the ostia of both the daughter arteries	SBP < 90 mm Hg for > 30 min or the requirement for supportive measures to maintain BP ≥ 90 mm Hg, and evidence of end-organ hypoperfusion (cool extremities, urine output < 30 mL/hr, and a heart rate ≥ 60 beats/min)	Further resuscitation was futile, other cause of shock, mechanical complication of MI	All-cause death, death because of cardiogenic shock, recurrent cardiac arrest, and a composite of these endpoints	6 months
Jaguszewski [19] 2013	2005–2012	158	85	Multicenter, retrospective	≥50% stenosis in ≥ 2 major coronary arteries and/or involving the LM	Killip class IV	NA	MACCE, all-cause death, MI, stroke	In-hospital
Yang [24] 2014	2005–2010	278	60	Multicenter, prospective	≥50% stenosis in ≥ 1 major non-IRA	SBP persistently < 90 mm Hg or vasopressors required to maintain BP > 90 mm Hg, signs of hypoperfusion (e.g., urine output < 30 mL/hr or cold/diaphoretic extremities or an altered mental status); and clinical evidence of left ventricular filling pressure (e.g., pulmonary congestion on physical examination or chest radiograph)	No primary PCI, mechanical complications such as ventricular septal defect or mitral regurgitation, LM disease	All-cause death, cardiac death, MI, revascularization, MACE	224 days
Zeymer [25] 2015	2008–2011	562	173	Multicenter, retrospective	>50% stenosis of 2 or 3 major vessels	SBP < 90 mm Hg, heart rate > 100 beats/min, and end organ hypoperfusion	LM disease, prior CABG	All-cause death, MI, stroke, bleeding, dialysis	In-hospital
Park [26] 2015	2006–2012	386	124	Multicenter, prospective, inverse probability of treatment weighting	≥1 major non-IRA with ≥ 50% stenosis	SBP < 90 mm Hg for > 30 min or the need for supportive management to maintain SBP ≥ 90 mm Hg and evidence of end-organ hypoperfusion (cool extremities, urine output < 30 mL/hr or altered mental status)	Missing initial vital signs information, NSTEMI	All-cause death, cardiac death, MI, revascularization, MACE	194 days

Table 1 (*continued*)

First Author Year	Study Period	Sample Size		Study Design	Definition of multivessel coronary artery disease	Definition of cardiogenic shock	Exclusion Criteria	Primary endpoint(s)	Follow-up
		CO-PCI	MV-PCI						
Hambraeus [27] 2016	2006–2010	263	67	Multicenter, prospective	NA	NA	SVD, prior GABG, missing data for revascularization status and missing time for the procedure	All-cause death, MI, and revascularization	1 year
Zeymer [28] 2017	2009–2012	284	167	Multicenter, post hoc analysis of RCT	Stenosis > 50% in ≥ 2 major coronary vessels	SBP < 90 mm Hg for > 30 min or catecholamines required to maintain BP > 90 mm Hg plus clinical signs of pulmonary congestion; signs of impaired organ perfusion with at least one of the following criteria: altered mental status, cold— clammy skin and extremities, oliguria with urine output < 30 mL/hr, serum lactate > 2.0 mmol/L	Resuscitation > 30 min, severe cerebral deficit, mechanical causes of cardiogenic shock, onset of shock > 12 h, shock of other cause, severe peripheral artery disease, age > 90 years, life expectancy < 6 months	All-cause death, MI, renal replacement, bleeding	1 year
McNeice [29] 2018	2008–2014	414	235	Multicenter, retrospective	Stenosis > 70% in ≥ 2 epicardial coronary arteries	Sustained (>30 min) episode of SBP < 90 mm Hg secondary to cardiac dysfunction, and/or the requirement for inotropic or mechanical support to maintain BP and adequate systemic perfusion	LM disease	All-cause death	1 year
Thiele [18] 2018	2013–2018	344	341	Multicenter, randomized, open-label	≥2 major vessels (≥2 mm in diameter) with > 70% stenosis	SBP < 90 mm Hg for > 30 min or the use of catechol- amine therapy to maintain SBP ≥ 90 mm Hg, clinical signs of pulmonary congestion, and signs of impaired organ perfusion with at least one of the following manifestations: altered mental status, cold and clammy skin and limbs, oliguria with urine output < 30 mL/hr, or arterial lactate level > 2.0 mmol/L	Resuscitation > 30 min, no intrinsic heart action, severe deficit in cerebral function, indication for primary CABG, shock > 12 h before randomization, age > 90 years, shock with a noncardiogenic cause, pulmonary embolism, renal insufficiency, life expectancy < 6 months	Composite of all-cause death or severe renal failure, all-cause death, MI, revascularization, heart faiulre	1 year
Lee [20] 2019	2011–2015	399	260	Multicenter, prospective	≥1 major non-IRA or LM with ≥ 50% stenosis.	SBP < 90 mm Hg for > 30 min or the need for supportive management to maintain SBP > 90 mm Hg; clinical signs of pulmonary congestion; and evidence of impaired end-organ perfusion with at least one of the following: cool extremities, decreased urine output, increased lactic acid level, or altered mental status	>12 h from onset of symptom, thrombolysis, suboptimal or failed PCI for IRA, lost to follow-up	All-cause death, MI, cardiac death, revascularization, stent thrombosis	3 years
Petrović [30] 2019	2007–2016	142	28	Single center, retrospective	NA	SBP < 90 mmHg for 30 min, vasopressors required to maintain SBP ≥ 90 mmHg; pulmonary congestion or elevated left ventricular filling pressures; signs of tissue perfusion disorder with at least one of the following criteria: altered mental status, cold, sticky skin, oliguria (<0.5 mL/kg/h); elevated serum lactate (>1.5 mmol/L)	Failed primary PCI or fatal outcome during intervention	In-hospital mortality	In-hospital
Lemor [31] 2019	2016–2019	39	69	single-arm, prospective, multicenter	NA	NA	NA	In-hospital mortality and acute kidney injury	In-hospital
Patients Complicated by CTO									

(*continued on next page*)

Table 1 (*continued*)

First Author Year	Study Period	Sample Size		Study Design	Definition of multivessel coronary artery disease	Definition of cardiogenic shock	Exclusion Criteria	Primary endpoint(s)	Follow-up
		CO-PCI	MV-PCI						
First Author Year	Inclusion Period	Sample Size CO-PCI	MV-PCI	Study Design	Definition of CTO	Definition of successful PCI	Exclusion Criteria	Primary endpoint(s)	Follow-up
Yang [32] 2013	2005–2008	49	87	Single center, retrospective	Total obstruction without antegrade flow with or without retrograde filling through collateral vessel	Residual diameter stenosis < 20% with TIMI grade 3 flow	Died during hospital stay or lost to follow-up	MACE including cardiac death, MI, revascularization and re-hospitalization for heart failure	2 years
Shi [33] 2014	2005–2009	48	100	Single center, retrospective	Total occlusion in a non-IRA before PCI without antegrade flow or with antegrade or retrograde filling through collateral vessels	Final diameter stenosis < 30% with a TIMI grade flow 3 of all the treated vessels without death, non-Q-wave or Q-wave MI, or emergency coronary surgery.	Loss to follow-up	MACE including cardiac death, MI, revascularization, and rehospitalization for heart failure	3 years
Valenti [34] 2014	2003–2012	111	58	Retrospective	Coronary obstruction with TIMI flow grade 0 and an estimated duration of > 3 months	Residual stenosis of the culprit lesion < 30% and a TIMI flow grade 3	In-hospital death during the first week after primary PCI	1- and 3-year cardiac survival	1 or 3 years
Choi [35] 2016	2004–2009	154	170	Multicenter, retrospective	TIMI flow 0 grade with or without anterograde or retrograde filling through collateral vessels	TIMI $\geq$ 2 final flow and residual stenosis < 30%	CABG or only medical therapy	All-cause mortality and a composite of cardiac death, MI, stroke, and revascularization.	5 years
Henriques [36] 2016	2007–2015	154	148	Multicenter, prospective	100% luminal narrowing without antegrade flow or with antegrade or retrograde filling through collateral vessels	Residual stenosis of IRA < 30% and TIMI $\geq$ 2	Hemodynamic instability persisting for > 48 h after primary PCI and factors precluding reliable CMR imaging such as persistent or permanent atrial fibrillation, severe renal insufficiency, and indications for pacemaker or implantable cardioverter-defibrillator insertion	LVEF and LVEDV	4 months
Lee [37] 2016	2003–2014	68	313	Multicenter, prospective,	Coronary artery obstruction with a TIMI of 0 within the occluded segment	Successful recanalization of the intended CTO lesion with DES implantation, restoration of TIMI flow grade 3, and residual diameter stenosis < 30% on visual assessment	Patients who underwent PCI for in-stent restenosis, underwent vein graft CTO-PCI, or received bare-metal stent implantation	Primary safety endpoints: all-cause mortality and a composite of all-cause death or Q-wave MI. Primary efficacy endpoint: TVR and CABG	4.6 years
Deng [38] 2018	2006–2014	156	221	Single center, retrospective	TIMI grade 0, and a complete obstruction of a native coronary artery > 3 months	NA	Died within 7 days or loss to follow-up	The composite of all-cause death, nonfatal MI, TVR, and hospitalization for heart failure	1 year
Park [39] 2018	2003–2012	101	321	Multicenter, prospective	Coronary obstruction with TIMI grade 0 $\geq$ 3 months	Angiographic residual stenosis of<30% in the presence of TIMI grade 3	Hemodynamically unstable, allergies to antiplatelet drugs, creatinine levels < 2.0 mg/dl, end-stage renal dysfunction, severe hepatic dysfunction, pregnant women, and life expectancy of up to 1 year	1-year survival	1 year

CABG: coronary artery bypass grafting, CAD: coronary artery disease, CI: cardiac index, CMR: cardiac magnetic resonance, DES: drug-eluting stent, IABP: intra-aortic balloon pump, LM: left main coronary artery, LVEDV: left ventricular end diastolic volume, LVEF: left ventricular ejection fraction, MACE: major adverse cardiovascular events, NSTEMI: non-ST-segment elevation myocardial infarction, SBP: systolic blood pressure, SVD: single-vessel disease, DES: drug-eluting stent, TVR: target vessel revascularization

Table 2
Baseline characteristics of patients in included studies.

First AuthorYear	Group	Age(years)	Male(%)	Hypertension (%)	Hyperlipidemia (%)	Diabetes (%)	Smoking (%)	Heart rate(beats/min)	SBP(mm Hg)	LVEF	Three vessel disease (%)
Patients complicated by cardiogenic shock											
Cavender [17] 2009	CO-PCIMV-PCI	66.3±12.866.4±13.0	64.764.2	63.459.8	50.750.6	27.330.5	62.156.1	NA	NA	NA	NA
van der Schaaf [12]2010	CO-PCIMV-PCI	67.4±11.467±13.3	67.781.1	25.829.7	24.224.3	21.824.3	29.829.7	NA	NA	NA	53.262.2
Bauer [22]2012	CO-PCIMV-PCI	65.4±12.267.2±12.2	6871	6760	5547	3540	5455	NA	NA	NA	4651
Cavender [23] 2013	CO-PCIMV-PCI	66±1363±14	6272	7972	2416	3135	7167	85±2194±27	107±26106±23	32±1424±9	5251
Mylotte [21]2013	CO-PCIMV-PCI	68.5±11.865±12.4	71.975.8	48.553	40.845.5	25.225.8	31.134.8	98±21.295±20	83±21.282±15.7	30.3±931±9.6	47.651.5
Jaguszewski [19] 2013	CO-PCIMV-PCI	65±11.264.7±11.7	74.777.6	61.156.5	57.939.7	2526.1	54.557.1	NA	NA	NA	NA
Yang [24]2014	CO-PCIMV-PCI	7057	57.963.3	57.950	23.421.7	16.521.7	35.640	66.5±32.771.8±35.2	83±3987.6±33.8	45.9±13.948.5±15.3	44.246.7
Zeymer [25]2015	CO-PCIMV-PCI	7068	7172	7881	6969	3539	3932	NA	NA	NA	6270
Park [26]2015	CO-PCIMV-PCI	6865.5	65.871	54.553.7	9.79.8	23.325.6	46.647.6	6266	8080	50.3±11.149.8±15.3	39.946
Hambraeus [27] 2016	CO-PCIMV-PCI	71.3±10.968.2±11.8	65.467.2	39.538.8	16.722.4	23.626.9	41.949.3	NA	NA	NA	51.325.4
Zeymer [28]2017	CO-PCIMV-PCI	68±1269±12	29.926.3	75.167.5	39.942.2	32.440.1	36.228.3	90±2696±27	92±2397±22	35±14.834.6±13.7	6272.5
McNeice [29] 2018	CO-PCIMV-PCI	NA	75.475.3	58.659.5	41.646.5	29.934.6	27.419.1	NA	NA	29.330.9	NA
Thiele [18]2018	CO-PCIMV-PCI	7070	74.978.1	5961.5	33.134.8	30.334.6	25.427.4	9091	85–13083–120	3330	63.663.2
Lee [20]2019	CO-PCIMV-PCI	67.3±12.866.2±12.4	74.973.5	54.652.3	46.646.9	40.941.2	36.340.4	NA	NA	47±12.744.3±13.2	33.333.8
Petrović [30]2019	CO-PCIMV-PCI	64.570.0	89.352.1	50.060.6	32.119.7	28.630.3	21.434.5	NA	NA	35.035.0	NA
Lemor [31]2019	CO-PCIMV-PCI	63.264.8	79.581.2	NA	NA	40.544.6	NA	NA	NA		
Patients complicated by CTO											
Yang [32]2013	CO-PCIMV-PCI	69 ± 1066 ± 11	8282	7670	2220	3736	3739	127	NA	47 ± 546 ± 7	6568
Shi [33]2014	CO-PCIMV-PCI	NA	83.378	68.865	58.355	22.923	39.645	NA	NA	NA	47.951
Valenti [34]2014	CO-PCIMV-PCI	69 ± 1464 ± 10	7385	6755	4136	1517	3050	5.45.1	NA	38 ± 1236 ± 11	4859
Choi [35]2016	CO-PCIMV-PCI	67.5 ± 11.262.7 ± 12.9	66.269.4	57.154.7	64.362.9	34.432.9	35.134.7	9.75.3	NA	49.6 ± 14.251.2 ± 13.0	NA
Henriques [36] 2016	CO-PCIMV-PCI	60 ± 1060 ± 10	8289	4540	3435	1615	4952	NA	NA	42 ± 1241 ± 11	4442
Lee [37]2016	CO-PCIMV-PCI	60.5 ± 9.359.4 ± 10.6	83.482.6	64.559.8	59.264.1	3231	23.127	4.71.9	NA	57.5 ± 8.557.6 ± 8.6	27.818.9
Deng [38]2018	CO-PCIMV-PCI	68.7 ± 10.165.1 ± 10.0	78.879.2	73.778.3	73.180.5	28.233.9	51.958.8	NA	NA	50.1 ± 9.449.3 ± 10.7	32.733.3
Park [39]2018	CO-PCIMV-PC	65 ± 12.464.1 ± 11.3	71.370.7	51.564.2	29.726.8	37.639.3	52.550.5	NA	NA	NA	57.451.1
First AuthorYear	Group	Age(years)	Male(%)	Hypertension (%)	Hyperlipidemia (%)	Diabetes (%)	Smoking (%)	Heart rate(beats/min)	SBP(mm Hg)	LVEF	Three vessel disease (%)
Patients complicated by cardiogenic shock											
Cavender2009	CO-PCIMV-PCI	66.3±12.866.4±13.0	64.764.2	63.459.8	50.750.6	27.330.5	62.156.1	NA	NA	NA	NA
van der Schaaf2010	CO-PCIMV-PCI	67.4±11.467±13.3	67.781.1	25.829.7	24.224.3	21.824.3	29.829.7	NA	NA	NA	53.262.2
Bauer2012	CO-PCIMV-PCI	65.4±12.267.2±12.2	6871	6760	5547	3540	5455	NA	NA	NA	4651
Cavender2013	CO-PCIMV-PCI	66±1363±14	6272	7972	2416	3135	7167	85±2194±27	107±26106±23	32±1424±9	5251
Mylotte2013	CO-PCIMV-PCI	68.5±11.865±12.4	71.975.8	48.553	40.845.5	25.225.8	31.134.8	98±21.295±20	83±21.282±15.7	30.3±931±9.6	47.651.5
Jaguszewski2013	CO-PCIMV-PCI	65±11.264.7±11.7	74.777.6	61.156.5	57.939.7	2526.1	54.557.1	NA	NA	NA	NA
Yang2014	CO-PCIMV-PCI	7057	57.963.3	57.950	23.421.7	16.521.7	35.640	66.5±32.771.8±35.2	83±3987.6±33.8	45.9±13.948.5±15.3	44.246.7
Zeymer2015	CO-PCIMV-PCI	7068	7172	7881	6969	3539	3932	NA	NA	NA	6270
Park2015	CO-PCIMV-PCI	6865.5	65.871	54.553.7	9.79.8	23.325.6	46.647.6	6266	8080	50.3±11.149.8±15.3	39.946
Hambraeus2016	CO-PCIMV-PCI	71.3±10.968.2±11.8	65.467.2	39.538.8	16.722.4	23.626.9	41.949.3	NA	NA	NA	51.325.4
Zeymer2017	CO-PCIMV-PCI	68±1269±12	29.926.3	75.167.5	39.942.2	32.440.1	36.228.3	90±2696±27	92±2397±22	35±14.834.6±13.7	6272.5
McNeice2018	CO-PCIMV-PCI	NA	75.475.3	58.659.5	41.646.5	29.934.6	27.419.1	NA	NA	29.330.9	NA
Thiele2018	CO-PCIMV-PCI	7070	74.978.1	5961.5	33.134.8	30.334.6	25.427.4	9091	85–13083–120	3330	63.663.2
Lee2019	CO-PCIMV-PCI	67.3±12.866.2±12.4	74.973.5	54.652.3	46.646.9	40.941.2	36.340.4	NA	NA	47±12.744.3±13.2	33.333.8
Petrović2019	CO-PCIMV-PCI	64.570.0	89.352.1	50.060.6	32.119.7	28.630.3	21.434.5	NA	NA	35.035.0	NA
Lemor2019	CO-PCIMV-PCI	63.264.8	79.581.2	NA	NA	40.544.6	NA	NA	NA		

(*continued on next page*)

Table 2 (*continued*)

First AuthorYear	Group	Age(years)	Male(%)	Hypertension (%)	Hyperlipidemia (%)	Diabetes (%)	Smoking (%)	Heart rate(beats/min)	SBP(mm Hg)	LVEF	Three vessel disease (%)
Patients complicated by CTO											
Yang2013	CO-PCIMV-PCI	69 ± 1066 ± 11	8282	7670	2220	3736	3739	127	NA	47 ± 546 ± 7	6568
Shi2014	CO-PCIMV-PCI	NA	83.378	68.865	58.355	22.923	39.645	NA	NA	NA	47.951
Valenti2014	CO-PCIMV-PCI	69 ± 1464 ± 10	7385	6755	4136	1517	3050	5.45.1	NA	38 ± 1236 ± 11	4859
Choi2016	CO-PCIMV-PCI	67.5 ± 11.262.7 ± 12.9	66.269.4	57.154.7	64.362.9	34.432.9	35.134.7	9.75.3	NA	49.6 ± 14.251.2 ± 13.0	NA
Henriques2016	CO-PCIMV-PCI	60 ± 1060 ± 10	8289	4540	3435	1615	4952	NA	NA	42 ± 1241 ± 11	4442
Lee2016	CO-PCIMV-PCI	60.5 ± 9.359.4 ± 10.6	83.482.6	64.559.8	59.264.1	3231	23.127	4.71.9	NA	57.5 ± 8.557.6 ± 8.6	27.818.9
Deng2018	CO-PCIMV-PCI	68.7 ± 10.165.1 ± 10.0	78.879.2	73.778.3	73.180.5	28.233.9	51.958.8	NA	NA	50.1 ± 9.449.3 ± 10.7	32.733.3
Park2018	CO-PCIMV-PC	65 ± 12.464.1 ± 11.3	71.370.7	51.564.2	29.726.8	37.639.3	52.550.5	NA	NA	NA	57.451.1

SBP: systolic blood pressure, LVEF: left ventricular ejection fraction.

(OR: 3.39; 95% CI: 0.79–14.61; I^2 = 87.0%) or long-term follow-up (OR: 1.26; 95% CI: 0.66–2.40; I^2 = 83.8%).

Secondary outcomes are detailed in Fig. 3. The long-term risk of cardiac death was similar between a CO-PCI strategy versus an immediate MV-PCI strategy (OR: 1.22; 95% CI: 0.46–3.19; I^2 = 86.9%; Fig. 3A). Similarly, the short-term (OR: 1.84; 95% CI: 0.72–4.74; I^2 = 0.0%) and long-term risks of heart failure (OR: 2.22; 95% CI: 0.58–8.56; I^2 = 75.1%; Fig. 3B) were also similar between a CO-PCI strategy versus an immediate MV-PCI strategy. With regard to the safety outcomes, a CO-PCI strategy was associated with a lower risk of short-term renal failure relative to an immediate MV-PCI strategy (OR: 0.75; 95% CI: 0.61–0.93; I^2 = 0.0%; Fig. 3D). There were no significant differences in the left safety outcomes.

3.3. Outcomes in patients complicated by CTO

In patients complicated by CTO, a significant increase in the risk of long-term MACE was observed with a CO-PCI strategy when compared with a staged MV-PCI strategy (OR: 2.06; 95% CI: 1.39–3.06; I^2 = 54.0%; Fig. 4A). Moreover, a CO-PCI strategy was inferior to a staged MV-PCI strategy for it increased the risk of long-term all-cause mortality (OR: 2.89; 95% CI: 2.09–4.00; I^2 = 0.0%; Fig. 4B). The risks of long-term re-infarction (OR: 1.69; 95% CI: 0.96–2.98; I^2 = 0.0%; Fig. 4D) and revascularization (OR: 1.16; 95% CI: 0.57–2.35; I^2 = 84.8%; Fig. 4D) between a CO-PCI strategy versus a staged MV-PCI strategy were similar.

However, the long-term risk of cardiac death was higher in a CO-PCI strategy versus a staged MV-PCI strategy in patients complicated by CTO (OR: 3.12; 95% CI: 2.05–4.75; I^2 = 16.8%; Fig. 5A). The long-term risk of heart failure was also higher in a CO-PCI strategy versus a staged MV-PCI strategy (OR: 1.99; 95% CI: 1.22–3.24; I^2 = 0.0%; Fig. 5B). A CO-PCI strategy was also associated with a higher risk of long-term stroke compared with a staged MV-PCI strategy (OR: 2.80; 95% CI: 1.04–7.53; I^2 = 0.0%; Fig. 5E), without significant differences in bleeding (OR: 0.38; 95% CI: 0.07–1.97; I^2 = NA; Fig. 5C) and re-infarction (OR: 1.69; 95% CI: 0.96–2.98; I^2 = 0.0%; Fig. 5D) between a CO-PCI strategy versus a staged MV-PCI strategy.

3.4. Sensitivity analyses and publication bias

The results of the sensitivity analyses were consistent with the main analysis (Supplementary Figs. 1–23). There was no evidence of publication bias for any of the above outcomes assessed (Supplementary Figs. 24–46).

4. Discussion

In this comprehensive *meta*-analysis, our findings were as follows: 1) In patients complicated by cardiogenic shock, a strategy of CO-PCI was associated with 25% lower risk for short-term renal failure, with no significant difference in MACE, all-cause mortality, re-infarction, revascularization, cardiac death, heart failure, major bleeding, or stroke compared with an immediate MV-PCI strategy. 2) In patients complicated by CTO, a CO-PCI strategy was associated with higher risk for MACE, all-cause mortality, cardiac death, heart failure, and stroke when compared with a staged MV-PCI strategy during long-term follow-up, without any difference in re-infarction, revascularization, or major bleeding.

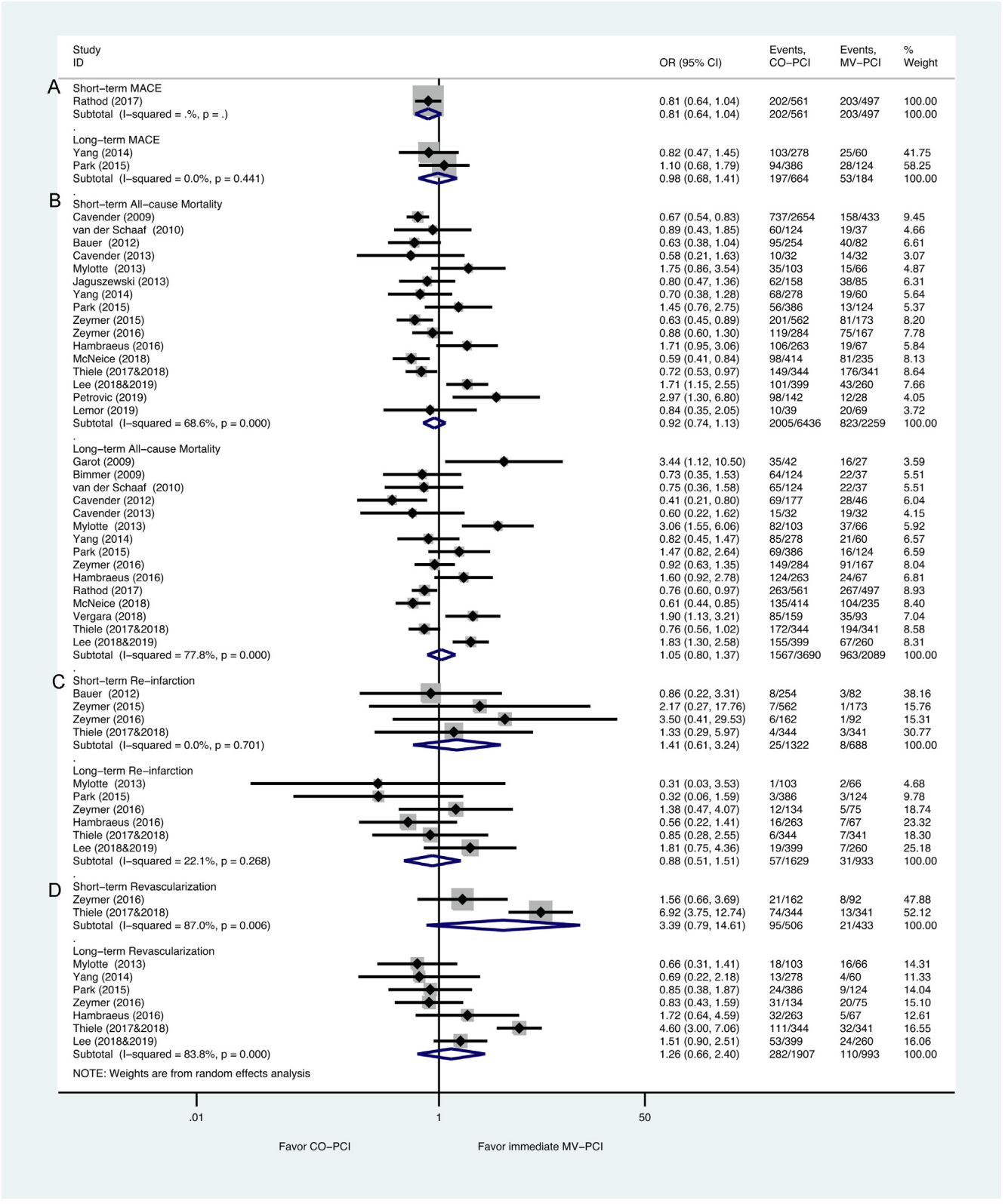

Fig. 2. Forest Plot of Primary Outcomes in Patients Complicated by Cardiogenic Shock Treated with Immediate MV-PCI or CO-PCI Strategy.

4.1. Cardiogenic shock and immediate MV-PCI strategy

The pathophysiology of cardiogenic shock is complex and multifactorial, including myocardial dysfunction caused by ischemia, an increase in diastolic stiffness, and the development of pulmonary congestion, hypoxia, hypotension, and tachycardia [40]. Moreover, activation of the inflammatory cascade contributes significantly to further vasodilation, hypotension, and hypoperfusion [41]. Taking into account the low aortic pressure and high left ventricular end-diastolic pressure in cardiogenic shock patients, an

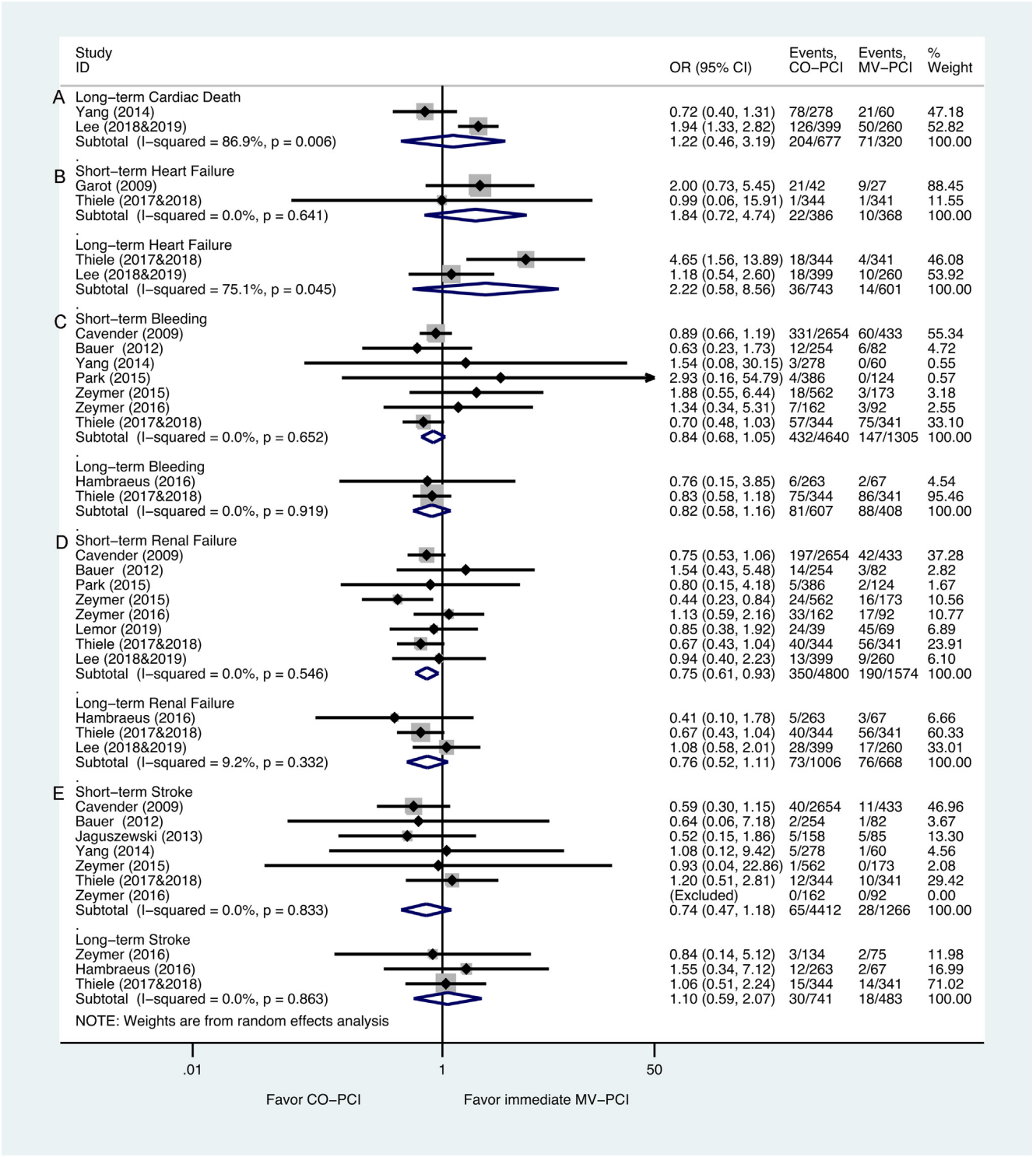

Fig. 3. Forest Plot of Secondary and Safety Outcomes in Patients Complicated by Cardiogenic Shock Treated with Immediate MV-PCI or CO-PCI Strategy.

immediate MV-PCI strategy may be theoretically beneficial in improving myocardial perfusion and ventricular function, and hence recovery from cardiogenic shock. Therefore, the 2016 American Heart Association (AHA) guidelines consider immediate revascularization of both IRA and non-IRA during the same procedure to be highly appropriate [42], and 2017 European Society of Cardiology (ESC) guidelines for the management of acute myocardial infarction in patients presenting with STEMI recommend non-IRA PCI during the index procedure (Class IIa, Level C) [43]. However, an immediate MV-PCI strategy may also lead to harm due to increased procedural time, more contrast use, prothrombotic and inflammatory milieu,[44] and periprocedural complications in the non-IRA, which in turn may lead to higher rates of stent thrombosis and myocardial infarction, even all-cause mortality. Furthermore, the major randomized trials for cardiogenic shock patients showed that death in patients with cardiogenic shock was mainly confined to the first 30 days, ranging from 39.7% to 46.7%, depending on the patients included in the trial, the revascu-

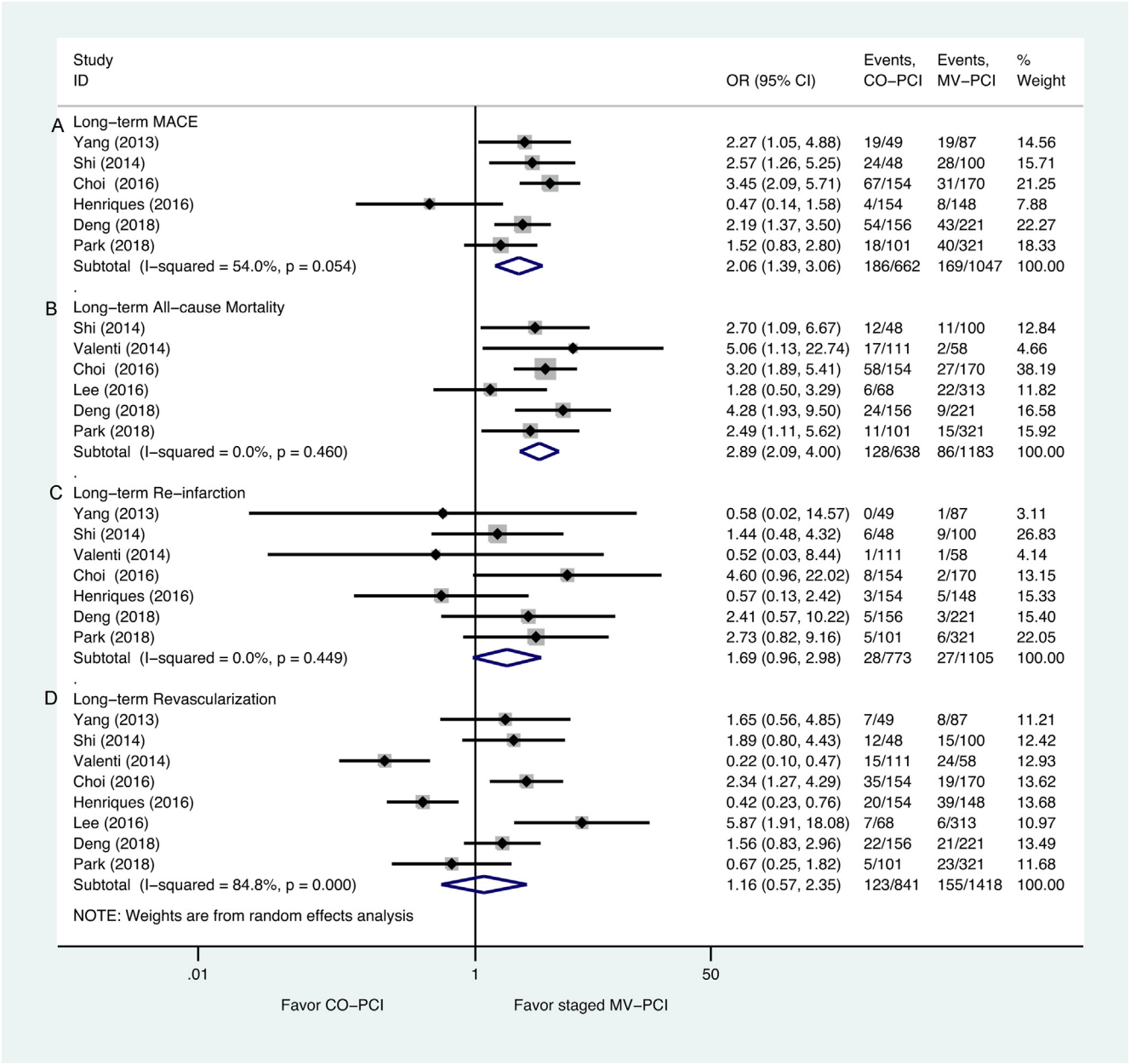

Fig. 4. Forest Plot of Primary Outcomes in Patients Complicated by CTO Treated with Staged MV-PCI or CO-PCI Strategy.

larization strategy, and the method of revascularization.[45–47] As indicated in our *meta*-analysis, an immediate MV-PCI strategy was associated with a higher risk of short-term renal failure, which can be explained by increased contrast load.[4] In the only randomized CULPRIT-SHOCK trial,[11,18] a total of 706 patients with cardiogenic shock from 83 European centers were randomly assigned to a CO-PCI arm (n = 351) or an immediate MV-PCI arm (n = 355). At 30 days (45.9% vs. 55.4%; RR: 0.83; 95% CI: 0.71–0.96) and one year (52.0% vs. 59.5%; RR: 0.87; 95% CI: 0.76–0.99), the composite primary endpoint of death or renal-replacement therapy were lower in the CO-PCI arm than that in the immediate MV-PCI arm. However, the rate of rehospitalization for congestive heart failure (5.2% vs. 1.2%; RR: 4.46; 95% CI: 1.53–13.04) and repeat revascularization (32.3% vs. 9.4%; RR: 3.44; 95% CI: 2.39–4.95) were higher in the CO-PCI arm than that in the MV-PCI arm at one year follow up. These findings indicated that in the very high-risk patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, an immediate MV-PCI strategy was not advocated due to the high rate of death or renal-replacement therapy. However, leaving the non-IRA untreated may increase the incidence of long-term rehospitalization for heart failure and revascularization. Therefore, in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, a staged MV-PCI strategy, which can reduce the composite of mortality and renal-replacement therapy caused by an immediate MV-PCI strategy and reduce the rehospitalization for heart failure and revascularization caused by a CO-PCI strategy, maybe the best option after stabilization of patients' condition.

Goldstein et al. [48] have demonstrated that the pathologic inflammatory process in STEMI involves not only the IRA but the entire coronary tree, and can lead to the destabilization and rupture of multiple atherosclerotic plaques, resulting in a sharply increased risk of death. Meanwhile, the dynamics of this specific inflammatory process are greatest in the first month after STEMI

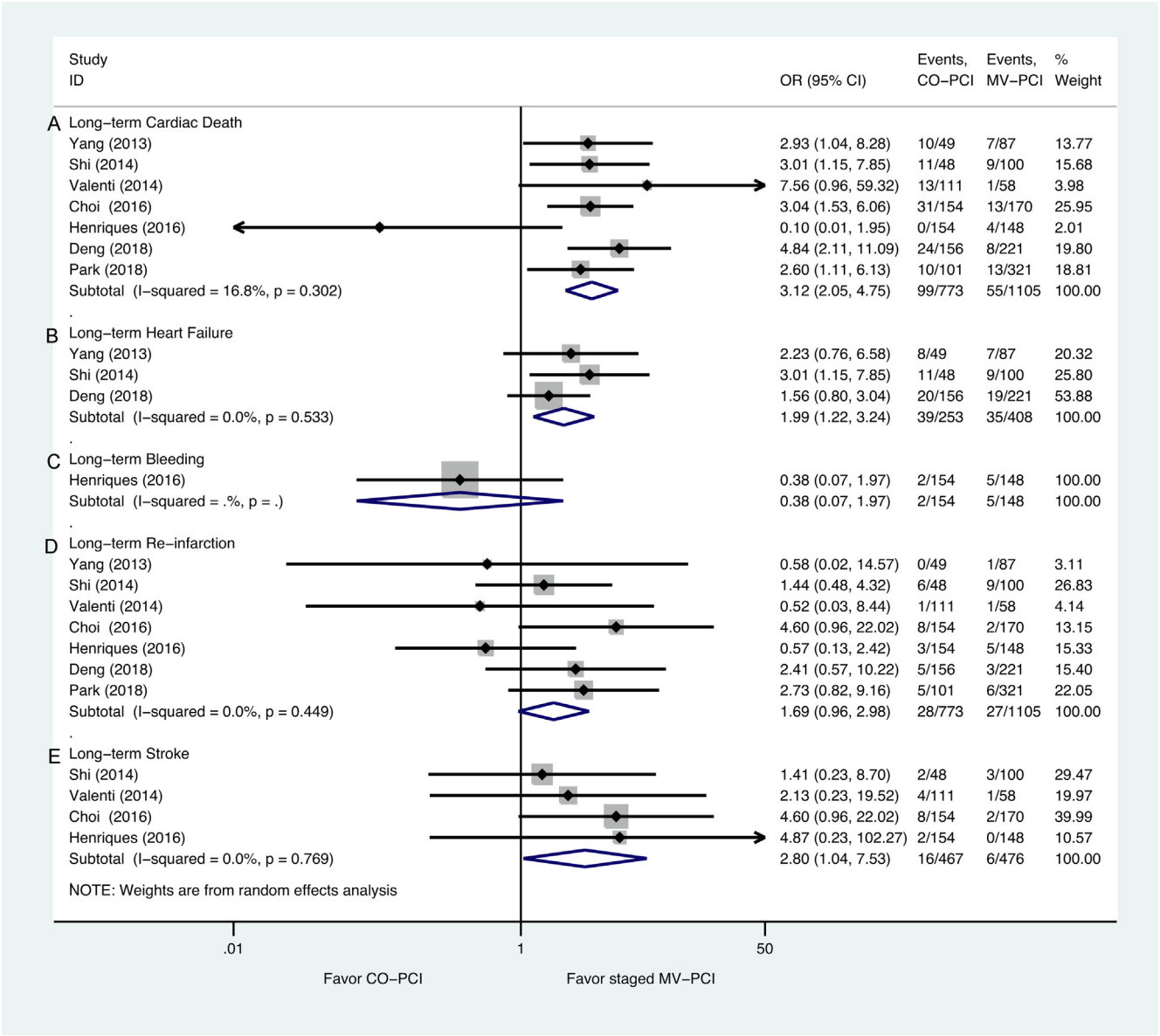

Fig. 5. Forest Plot of Secondary and Safety Outcomes in Patients Complicated by CTO Treated with Staged MV-PCI or CO-PCI Strategy.

[49,50]. Therefore, performing immediate MV-PCI in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock may increase the risk of all-cause mortality. In that case, a staged MV-PCI strategy, which performed after stabilization of patients' condition, may be the best strategy. However, no studies are dedicated to comparing the outcomes between a CO-PCI strategy versus a staged MV-PCI strategy in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, therefore, further studies are warranted to confirm the best PCI strategy in these patients.

4.2. CTO and staged MV-PCI strategy

An increasing body of evidence suggests that the excess morbidity and mortality exhibited in patients with multivessel coronary artery disease compared with patients with single-vessel coronary artery disease are mainly explained by the presence of concurrent CTO [13,51]. A *meta*-analysis in patients with CTO also revealed that successful recanalization of a CTO resulted in an overall improvement of absolute left ventricular ejection fraction (LVEF), reduced adverse remodeling and an improvement of survival [52]. However, it remains unclear whether successful staged recanalization of CTO in the non-IRA could improve clinical outcomes in patients with STEMI and multivessel coronary artery disease complicated by CTO. Current literature contains several reports addressing the effect of CTO-PCI in the non-IRA, but they are small observational studies which could under or overestimate the true effect of CTO-PCI. For this reason, we decided to perform a *meta*-analysis of the literature describing the impact of CTO-PCI in the non-IRA that has never been reported before.

In our *meta*-analysis, successful CTO-PCI in a staged procedure in patients with STEMI and multivessel coronary artery disease complicated by CTO was associated with lower risks of MACE, all-cause mortality, cardiac death, heart failure, and stroke without increasing the risks of re-infarction, revascularization, or major bleeding.

Possible explanation of the clinical benefit in CTO-PCI maybe related to the following mechanisms. First, improvement in the healing process of the infarct border zone. Due to the disruption of blood supply, some myocardium located in the infarct border

zone changes from viable myocardium into stunning myocardium, and it is now widely accepted that repetitive episodes of stunning such as myocardial ischemia would lead to the development of myocardial apoptosis [53]. However, the stunning myocardium will become viable with the restoration of myocardial blood supply. Second, restoration of the contractile function of hibernating myocardium. A *meta*-analysis including 34 articles and 2243 patients indicated that after successful CTO-PCI, LVEF increased with 4.44% (95% CI: 3.52–5.35; P < 0.01) compared with baseline. Meanwhile, eight studies reported that the left ventricular end-diastolic volume (LVEDV) decreased 6.14 mL/m^2 (95% CI: −9.31 to − 2.97; P < 0.01) after successful CTO-PCI in a total of 412 patients. Successful CTO-PCI was also associated with reduced mortality in comparison with failed CTO-PCI (OR: 0.52; 95% CI: 0.43–0.62; P < 0.01). [52] Therefore, successful CTO-PCI could translate into improvement in left ventricular function, slowdown of ventricular remodeling, decrease in electrical instability, and increase in tolerance of future coronary occlusion events.

In our *meta*-analysis, short-term outcomes within 30 days were not available. Therefore, the short-term outcomes in patients with STEMI and multivessel coronary artery disease receiving successful CTO-PCI remain unknown. However, the HORIZONS-AMI trial[13] showed that multivessel coronary artery disease with CTO in a non-IRA was an independent predictor of both short term (0–30-day; HR: 2.88; 95% CI: 1.41–5.88; P = 0.004) and long-term mortality (30-day to 3-year; HR: 1.98; 95% CI: 1.19–3.29; P = 0.009), whereas multivessel coronary artery disease without CTO in a non-IRA was only an independent predictor of short term (0–30-day; HR: 2.20; 95% CI: 1.00–3.06; P = 0.049) but not long-term mortality. Therefore, it is likely that performing staged MV-PCI in patients with STEMI and multivessel coronary artery disease complicated by CTO is beneficial for both short-term and long-term outcomes.

4.3. Extrapolation of the MV-PCI strategy

Recent *meta*-analyses [54–56] based on randomized trials and the largest COMPLETE Trial [7] all concluded that MV-PCI strategy (immediate or staged) was superior to CO-PCI strategy in reducing the risks of re-infarction and cardiac death. However, caution is advised when extrapolating these findings to patients complicated by cardiogenic shock or CTO, as these patients with high risks were excluded from the majority of randomized trials. These patients complicated CTO, with the so-called "double jeopardy" of a non-IRA CTO in the context of STEMI, intuitively have a poorer prognosis due to larger ischemic territories and higher rates of cardiogenic shock at presentation [57].

Our *meta*-analysis suggested that for patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, immediate multivessel PCI was not advocated due to higher risk for short-term renal failure, whereas for patients complicated by CTO, staged multivessel PCI was advocated due to reduced risks for MACE, all-cause mortality, cardiac death, heart failure, and stroke. The mechanisms underlying the poor prognosis with an immediate MV-PCI strategy are likely multifactorial. First, the acute phase of STEMI is a highly unstable condition including hemodynamic instability, heart failure, arrhythmia, and resuscitation. Many early deaths occur after STEMI onset due to ventricular fibrillation [58]. Second, the acute phase of STEMI is an extremely prothrombotic and inflammatory milieu [44]. Therefore, PCI of non-IRA not only has no strong indication but also has the risk of more severe complications due to lesion instability. Third, coronary spasm caused by endothelial dysfunction or use of catecholamine is frequently present in the acute phase of STEMI, which may lead to possible overestimation of stenosis severity in non-IRA and perform unnecessary PCI [59]. Fourth, unforeseen periprocedural complications in the non-IRA may be poorly tolerated due to the "double jeopardy" of the IRA and non-IRA regions [60]. Fifth, prolonged procedure time leads to increased radiation exposure. Finally, immediate MV-PCI may be associated with increased contrast load [61] and further increase the risk of contrast-induced nephropathy. The advantage of the staged MV-PCI is that operators have more time to appropriately evaluate the risks and benefits of additional revascularization, perhaps resulting in better patient selection [62]. Furthermore, it is safer to perform PCI of non-IRA after stabilization of STEMI patient's condition. However, due to the lack of sufficient randomized trials comparing different revascularization strategies in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock or CTO, the results should be interpreted with caution. Further studies are warranted to confirm the best revascularization strategy in patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock or CTO.

4.4. Limitations

First, among the included studies, except for CULPRIT-SHOCK [11,18] trial, the left studies were nonrandomized and had all limitations of observational data including selection bias and unmeasured confounding. Second, many of these studies had different study periods, design, sample size, definition of multivessel coronary artery disease, exclusion criteria, and follow-up time, which is a source of increased heterogeneity that may limit the generalization of our conclusions. We attempted to mitigate this heterogeneity by performing our analysis with a random effects model and subgroups were made based on follow-up time. Third, ACC-NCDR [17] was the study containing the largest number of patients (35.50%), therefore, the results of our *meta*-analysis could have been skewed toward biases within the ACC-NCDR study. However, the sensitivity analyses by excluding this study yielded similar results to the main analysis. Fourth, there are concerns that PCI procedure for CTO is associated with a greater incidence of contrast nephropathy, but the incidence of contrast nephropathy was not available in our *meta*-analysis. However, these conditions might lead to worse outcomes in patients with chronic kidney disease but not in patients with normal renal function [35]. Moreover, the great merits in MACE, all-cause mortality, cardiac death, heart failure, and stroke with a staged MV-PCI strategy outweigh the risk of contrast nephropathy. Fifth, a lack of patient-level data precluded a full evaluation for differences in patient-level covariates across comparisons.

5. Conclusions

For patients with STEMI and multivessel coronary artery disease complicated by cardiogenic shock, a CO-PCI strategy was associated with a lower risk of short-term renal failure compared with an immediate MV-PCI strategy, whereas in patients complicated by CTO, a CO-PCI strategy was associated with higher risks for MACE, all-cause mortality, cardiac death, heart failure, and stroke compared with a staged MV-PCI strategy during long-term follow-up.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by the CAMS Innovation Fund for Medical Sciences (2016-I2M-1-009, Beijing, China)and the Twelfth

Five-Year Planning Project of the Scientific and Technological Department of China (2011BAI11B02).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcha.2021.100813.

References

[1] B.E. Jaski, J.D. Cohen, J. Trausch, D.G. Marsh, G.R. Bail, P.A. Overlie, E.W. Skowronski, S.C. Smith, Outcome of urgent percutaneous transluminal coronary angioplasty in acute myocardial infarction: comparison of single-vessel versus multivessel coronary artery disease, Am. Heart J. 124 (6) (1992) 1427–1433.

[2] R. Moreno, E. García, J. Elízaga, et al., Results of primary angioplasty in patients with multivessel disease, Rev. Esp. Cardiol. 51 (1998) 547–555.

[3] D.S. Wald, J.K. Morris, N.J. Wald, A.J. Chase, R.J. Edwards, L.O. Hughes, C. Berry, K.G. Oldroyd, Randomized trial of preventive angioplasty in myocardial infarction, N. Engl. J. Med. 369 (12) (2013) 1115–1123.

[4] A.H. Gershlick, J.N. Khan, D.J. Kelly, et al., Randomized trial of complete versus lesion-only revascularization in patients undergoing primary percutaneous coronary intervention for STEMI and multivessel disease: the CvLPRIT trial, J. Am. Coll. Cardiol. 65 (2015) 963–972.

[5] T. Engstrøm, H. Kelbæk, S. Helqvist, D.E. Høfsten, L. Kløvgaard, L. Holmvang, E. Jørgensen, F. Pedersen, K. Saunamäki, P. Clemmensen, O. De Backer, J. Ravkilde, H.-H. Tilsted, A.B. Villadsen, J. Aarøe, S.E. Jensen, B. Raungaard, L. Køber, Complete revascularisation versus treatment of the culprit lesion only in patients with ST-segment elevation myocardial infarction and multivessel disease (DANAMI-3—PRIMULTI): an open-label, randomised controlled trial, Lancet (London, England) 386 (9994) (2015) 665–671.

[6] P.C. Smits, M. Abdel-Wahab, F.-J. Neumann, B.M. Boxma-de Klerk, K. Lunde, C. E. Schotborgh, Z. Piroth, D. Horak, A. Wlodarczak, P.J. Ong, R. Hambrecht, O. Angerås, G. Richardt, E. Omerovic, Fractional Flow Reserve-Guided Multivessel Angioplasty in Myocardial Infarction, N. Engl. J. Med. 376 (13) (2017) 1234–1244.

[7] S.R. Mehta, D.A. Wood, R.F. Storey, R. Mehran, K.R. Bainey, H. Nguyen, B. Meeks, G. Di Pasquale, J. López-Sendón, D.P. Faxon, L. Mauri, S.V. Rao, L. Feldman, P.G. Steg, Á. Avezum, T. Sheth, N. Pinilla-Echeverri, R. Moreno, G. Campo, B. Wrigley, S. Kedev, A. Sutton, R. Oliver, J. Rodés-Cabau, G. Stanković, R. Welsh, S. Lavi, W.J. Cantor, J. Wang, J. Nakamya, S.I. Bangdiwala, J.A. Cairns, Complete Revascularization with Multivessel PCI for Myocardial Infarction, N. Engl. J. Med. 381 (15) (2019) 1411–1421.

[8] M. Anantha Narayanan, Y.N.V. Reddy, V. Sundaram, Y.N.V. Reddy, J. Baskaran, K. Agnihotri, A. Badheka, N. Patel, A. Deshmukh, What is the optimal approach to a non- culprit stenosis after ST-elevation myocardial infarction - Conservative therapy or upfront revascularization? An updated meta-analysis of randomized trials, Int. J. Cardiol. 216 (2016) 18–24.

[9] I.Y. Elgendy, T. Huo, A. Mahmoud, A.A. Bavry, Complete versus culprit-only revascularization in patients with multi-vessel disease undergoing primary percutaneous coronary intervention: A meta-analysis of randomized trials, Int. J. Cardiol. 186 (2015) 98–103.

[10] A. Reyentovich, M.H. Barghash, J.S. Hochman, Management of refractory cardiogenic shock, Nat. Rev. Cardiol. 13 (8) (2016) 481–492.

[11] H. Thiele, I. Akin, M. Sandri, G. Fuernau, S. de Waha, R. Meyer-Saraei, P. Nordbeck, T. Geisler, U. Landmesser, C. Skurk, A. Fach, H. Lapp, J.J. Piek, M. Noc, T. Goslar, S.B. Felix, L.S. Maier, J. Stepinska, K. Oldroyd, P. Serpytis, G. Montalescot, O. Barthelemy, K. Huber, S. Windecker, S. Savonitto, P. Torremante, C. Vrints, S. Schneider, S. Desch, U. Zeymer, PCI Strategies in Patients with Acute Myocardial Infarction and Cardiogenic Shock, N. Engl. J. Med. 377 (25) (2017) 2419–2432.

[12] R.J. van der Schaaf, B.E. Claessen, M.M. Vis, L.P. Hoebers, K.T. Koch, J. Baan, M. Meuwissen, A.E. Engstrom, W.J. Kikkert, J.G.P. Tijssen, R.J. de Winter, J.J. Piek, J. P.S. Henriques, Effect of multivessel coronary disease with or without concurrent chronic total occlusion on one-year mortality in patients treated with primary percutaneous coronary intervention for cardiogenic shock, Am. J. Cardiol. 105 (7) (2010) 955–959.

[13] B.E. Claessen, G.D. Dangas, G. Weisz, B. Witzenbichler, G. Guagliumi, M. Mockel, S.J. Brener, K. Xu, J.P.S. Henriques, R. Mehran, G.W. Stone, Prognostic impact of a chronic total occlusion in a non-infarct-related artery in patients with ST-segment elevation myocardial infarction: 3-year results from the HORIZONS-AMI trial, Eur. Heart J. 33 (6) (2012) 768–775.

[14] A. Liberati, D.G. Altman, J. Tetzlaff, C. Mulrow, P.C. Gotzsche, J.P.A. Ioannidis, M. Clarke, P.J. Devereaux, J. Kleijnen, D. Moher, The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration, BMJ 339 (jul21 1) (2009) b2700.

[15] J.P. Higgins, S.G. Thompson, J.J. Deeks, D.G. Altman, Measuring inconsistency in meta-analyses, BMJ 327 (2003) 557–560.

[16] M. Egger, G.D. Smith, M. Schneider, C. Minder, Bias in meta-analysis detected by a simple, graphical test, BMJ 315 (7109) (1997) 629–634.

[17] M.A. Cavender, S. Milford-Beland, M.T. Roe, E.D. Peterson, W.S. Weintraub, S.V. Rao, Prevalence, predictors, and in-hospital outcomes of non-infarct artery intervention during primary percutaneous coronary intervention for ST-segment elevation myocardial infarction (from the National Cardiovascular Data Registry), Am. J. Cardiol. 104 (4) (2009) 507–513.

[18] H. Thiele, I. Akin, M. Sandri, S. de Waha-Thiele, R. Meyer-Saraei, G. Fuernau, I. Eitel, P. Nordbeck, T. Geisler, U. Landmesser, C. Skurk, A. Fach, A. Jobs, H. Lapp, J.J. Piek, M. Noc, T. Goslar, S.B. Felix, L.S. Maier, J. Stepinska, K. Oldroyd, P. Serpytis, G. Montalescot, O. Barthelemy, K. Huber, S. Windecker, L. Hunziker, S. Savonitto, P. Torremante, C. Vrints, S. Schneider, U. Zeymer, S. Desch, One-Year Outcomes after PCI Strategies in Cardiogenic Shock, N. Engl. J. Med. 379 (18) (2018) 1699–1710.

[19] M. Jaguszewski, D. Radovanovic, B.K. Nallamothu, T.F. Lüscher, P. Urban, F.R. Eberli, O. Bertel, G.B. Pedrazzini, S. Windecker, R. Jeger, P. Erne, Multivessel versus culprit vessel percutaneous coronary intervention in ST-elevation myocardial infarction: is more worse?, EuroIntervention 9 (8) (2013) 909–915.

[20] J.M. Lee, T.M. Rhee, H.K. Kim, et al., Comparison of Long-Term Clinical Outcome Between Multivessel Percutaneous Coronary Intervention Versus Infarct-Related Artery-Only Revascularization for Patients With ST-Segment-Elevation Myocardial Infarction With Cardiogenic Shock, J. Am. Heart Assoc. 8 (2019) e013870.

[21] D. Mylotte, M.-C. Morice, H. Eltchaninoff, J. Garot, Y. Louvard, T. Lefèvre, P. Garot, Primary percutaneous coronary intervention in patients with acute myocardial infarction, resuscitated cardiac arrest, and cardiogenic shock: the role of primary multivessel revascularization, JACC Cardiovasc. Interv. 6 (2) (2013) 115–125.

[22] T. Bauer, U. Zeymer, M. Hochadel, H. Möllmann, F. Weidinger, R. Zahn, H.M. Nef, C.W. Hamm, J. Marco, A.K. Gitt, Use and outcomes of multivessel percutaneous coronary intervention in patients with acute myocardial infarction complicated by cardiogenic shock (from the EHS-PCI Registry), Am. J. Cardiol. 109 (7) (2012) 941–946.

[23] M.A. Cavender, J. Rajeswaran, L. DiPaola, et al., Outcomes of culprit versus multivessel PCI in patients with multivessel coronary artery disease presenting with ST-elevation myocardial infarction complicated by shock, J. Invasive Cardiol. 25 (2013) 218–224.

[24] J.H. Yang, J.-Y. Hahn, P.S. Song, Y.B. Song, S.-H. Choi, J.-H. Choi, S.H. Lee, M.-H. Jeong, D.-J. Choi, Y.J. Kim, H.-C. Gwon, Percutaneous coronary intervention for nonculprit vessels in cardiogenic shock complicating ST-segment elevation acute myocardial infarction, Crit. Care Med. 42 (1) (2014) 17–25.

[25] U. Zeymer, M. Hochadel, H. Thiele, D. Andresen, H. Schühlen, J. Brachmann, A. Elsässer, A. Gitt, R. Zahn, Immediate multivessel percutaneous coronary intervention versus culprit lesion intervention in patients with acute myocardial infarction complicated by cardiogenic shock: results of the ALKK-PCI registry, EuroIntervention 11 (3) (2015) 280–285.

[26] J.S. Park, K.S. Cha, D.S. Lee, D. Shin, H.W. Lee, J.-H. Oh, J.S. Kim, J.H. Choi, Y.H. Park, H.C. Lee, J.H. Kim, K.-J. Chun, T.J. Hong, M.H. Jeong, Y. Ahn, S.C. Chae, Y.J. Kim, Culprit or multivessel revascularisation in ST-elevation myocardial infarction with cardiogenic shock, Heart 101 (15) (2015) 1225–1232.

[27] K. Hambraeus, K. Jensevik, B.o. Lagerqvist, B. Lindahl, R. Carlsson, R. Farzaneh-Far, T. Kellerth, E. Omerovic, G. Stone, C. Varenhorst, S. James, Long-Term Outcome of Incomplete Revascularization After Percutaneous Coronary Intervention in SCAAR (Swedish Coronary Angiography and Angioplasty Registry), JACC Cardiovasc. Interv. 9 (3) (2016) 207–215.

[28] U. Zeymer, K. Werdan, G. Schuler, R. Zahn, F.-J. Neumann, G. Fürnau, S. de Waha, S. Schneider, H. Thiele, Editor's Choice- Impact of immediate multivessel percutaneous coronary intervention versus culprit lesion intervention on 1-year outcome in patients with acute myocardial infarction complicated by cardiogenic shock: Results of the randomised IABP-SHOCK II trial, Eur. Heart J. Acute. Cardiovasc. Care 6 (7) (2017) 601–609.

[29] A. McNeice, I.J. Nadra, S.D. Robinson, et al., The prognostic impact of revascularization strategy in acute myocardial infarction and cardiogenic shock: insights from the British Columbia Cardiac Registry, Catheteriz. Cardiovas. Interv. (2018) (no pagination).

[30] M. Petrovic, M. Jarakovic, M. Cankovic, I. Srdanovic, M. Kovacevic, D. Tesic, V. Ivanovic, A. Redzek, L. Velicki, Complete percutaneous myocardial revascularization in patients with STEMI complicated by cardiogenic shock, Vojnosanit. Pregl. 76 (2) (2019) 152–160.

[31] A. Lemor, M. Basir, K. Patel, et al., TCT-813 Culprit-Vessel Versus Multivessel Percutaneous Coronary Intervention in Cardiogenic Shock: insights From the National Cardiogenic Shock Initiative, J. Am. College Cardiol. 74 (2019) B796.

[32] Z.K. Yang, R.Y. Zhang, J. Hu, Q.i. Zhang, F.H. Ding, W.F. Shen, Impact of successful staged revascularization of a chronic total occlusion in the non-infarct-related artery on long-term outcome in patients with acute ST-segment elevation myocardial infarction, Int. J. Cardiol. 165 (1) (2013) 76–79.

[33] G. Shi, P. He, Y. Liu, Y. Lin, X. Yang, J. Chen, Y. Zhou, N. Tan, Evaluation of the effect of concurrent chronic total occlusion and successful staged revascularization on long-term mortality in patients with ST-elevation myocardial infarction, Sci. World J. 2014 (2014) 1–9.

[34] R. Valenti, M. Marrani, G. Cantini, A. Migliorini, N. Carrabba, R. Vergara, G. Cerisano, G. Parodi, D. Antoniucci, Impact of chronic total occlusion revascularization in patients with acute myocardial infarction treated by primary percutaneous coronary intervention, Am. J. Cardiol. 114 (12) (2014) 1794–1800.

[35] I.J. Choi, Y.-S. Koh, S. Lim, E.H. Choo, J.J. Kim, B.-H. Hwang, T.-H. Kim, S.M. Seo, C.J. Kim, M.-W. Park, D.I. Shin, Y.-S. Choi, H.-J. Park, S.-H. Her, D.-B. Kim, C.S. Park, J.-M. Lee, K.W. Moon, K. Chang, H.Y. Kim, K.-D. Yoo, D.S. Jeon, W.-S. Chung, Y. Ahn, M.H. Jeong, K.-B. Seung, P.-J. Kim, Impact of Percutaneous Coronary Intervention for Chronic Total Occlusion in Non-Infarct-Related Arteries in Patients With Acute Myocardial Infarction (from the COREA-AMI Registry), Am. J. Cardiol. 117 (7) (2016) 1039–1046.

[36] J.P.S. Henriques, L.P. Hoebers, T. Råmunddal, P. Laanmets, E. Eriksen, M. Bax, D. Ioanes, M.J. Suttorp, B.H. Strauss, E. Barbato, R. Nijveldt, A.C. van Rossum, K.M. Marques, J. Elias, I.M. van Dongen, B.E.P.M. Claessen, J.G. Tijssen, R.J. van der Schaaf, J.P.S. Henriques, R. van der Schaaf, J.G.P. Tijssen, F. Zijlstra, M.-J. de Boer, R. Michels, M. Meuwissen, P. Agostoni, K.G. van Houwelingen, H.J. Verberne, A. Hirsch, J.P.S. Henriques, J.J. Piek, R.J. de Winter, K.T. Koch, M.M. Vis, J. Baan, J. Wykrzykowska, T. Råmunddal, D. Ioanes, P. Laanmets, R.J. van der Schaaf, T. Slagboom, G. Amoroso, E. Eriksen, V. Tuseth, M. Bax, C.E. Schotborgh, M.J. Suttorp, B.H. Strauss, E. Barbato, K.M. Marques, O. Bertrand, M. Meuwissen, M. van der Ent, J. Koolen, Percutaneous Intervention for Concurrent Chronic Total Occlusions in Patients With STEMI: The EXPLORE Trial, J. Am. Coll. Cardiol. 68 (15) (2016) 1622–1632.

[37] P.H. Lee, S.W. Lee, H.S. Park, et al., Successful Recanalization of Native Coronary Chronic Total Occlusion Is Not Associated With Improved Long-Term Survival, JACC Cardiovasc. Interv. 9 (2016) 530–538.

[38] J. Deng, X. Wang, Y. Shi, X. Zhao, Y. Han, Prognostic value of the age, creatinine, and ejection fraction score for non-infarct-related chronic total occlusion revascularization after primary percutaneous intervention in acute ST-elevation myocardial infarction patients: A retrospective study, J. Interv. Cardiol. 31 (1) (2018) 33–40.

[39] J.Y. Park, B.G. Choi, S.-W. Rha, T.S. Kang, C.U. Choi, C.W. Yu, H.-C. Gwon, I.-H. Chae, H.-S. Kim, H.S. Park, S.-H. Lee, M.-H. Kim, S.-H. Hur, Y. Jang, Chronic total occlusion intervention of the non-infarct-related artery in acute myocardial infarction patients: the Korean multicenter chronic total occlusion registry, Coron. Artery Dis. 29 (6) (2018) 495–501.

[40] S.M. Hollenberg, C.J. Kavinsky, J.E. Parrillo, Cardiogenic shock, Ann. Intern. Med. 131 (1) (1999) 47, https://doi.org/10.7326/0003-4819-131-1-199907060-00010.

[41] S. Kohsaka, V. Menon, A.M. Lowe, et al., Systemic inflammatory response syndrome after acute myocardial infarction complicated by cardiogenic shock, Arch. Intern. Med. 165 (2005) 1643–1650.

[42] M.R. Patel, J.H. Calhoon, G.J. Dehmer, J.A. Grantham, T.M. Maddox, D.J. Maron, P.K. Smith, ACC/AATS/AHA/ASE/ASNC/SCAI/SCCT/STS 2016 Appropriate Use Criteria for Coronary Revascularization in Patients With Acute Coronary Syndromes: A Report of the American College of Cardiology Appropriate Use Criteria Task Force, American Association for Thoracic Surgery, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, and the Society of Thoracic Surgeons, J. Am. Coll. Cardiol. 69 (5) (2017) 570–591.

[43] B. Ibanez, S. James, S. Agewall, M.J. Antunes, C. Bucciarelli-Ducci, H. Bueno, A.L. P. Caforio, F. Crea, J.A. Goudevenos, S. Halvorsen, G. Hindricks, A. Kastrati, M.J. Lenzen, E. Prescott, M. Roffi, M. Valgimigli, C. Varenhorst, P. Vranckx, P. Widimský, J.-P. Collet, S.D. Kristensen, V. Aboyans, A. Baumbach, R. Bugiardini, I.M. Coman, V. Delgado, D. Fitzsimons, O. Gaemperli, A.H. Gershlick, S. Gielen, V.-P. Harjola, H.A. Katus, J. Knuuti, P. Kolh, C. Leclercq, G.Y.H. Lip, J. Morais, A.N. Neskovic, F.-J. Neumann, A. Niessner, M.F. Piepoli, D.J. Richter, E. Shlyakhto, I.A. Simpson, P.G. Steg, C.J. Terkelsen, K. Thygesen, S. Windecker, J.L. Zamorano, U. Zeymer, S. Windecker, V. Aboyans, S. Agewall, E. Barbato, H. Bueno, A. Coca, J.-P. Collet, I.M. Coman, V. Dean, V. Delgado, D. Fitzsimons, O. Gaemperli, G. Hindricks, B. Iung, P. Jüni, H.A. Katus, J. Knuuti, P. Lancellotti, C. Leclercq, T. McDonagh, M.F. Piepoli, P. Ponikowski, D.J. Richter, M. Roffi, E. Shlyakhto, I.A. Simpson, J.L. Zamorano, M. Chettibi, H.G. Hayrapetyan, B. Metzler, F. Ibrahimov, V. Sujayeva, C. Beauloye, L. Dizdarevic-Hudic, K. Karamfiloff, B. Skoric, L. Antoniades, P. Tousek, P.J. Terkelsen, S.M. Shaheen, T. Marandi, M. Niemelä, S. Kedev, M. Gilard, A. Aladashvili, A. Elsaesser, I.G. Kanakakis, B. Merkely, T. Gudnason, Z. Iakobishvili, L. Bolognese, S. Berkinbayev, G. Bajraktari, M. Beishenkulov, I. Zake, H.B. Lamin, O. Gustiene, B. Pereira, R.G. Xuereb, S. Ztot, V. Juliebø, J. Legutko, A.T. Timóteo, G. Tatu-Chiţoiu, A. Yakovlev, L. Bertelli, M. Nedeljkovic, M. Studenčan, M. Bunc, A.M. García de Castro, P. Petursson, R. Jeger, M.S. Mourali, A. Yildirir, A. Parkhomenko, C.P. Gale, 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC), Eur. Heart J. 39 (2) (2018) 119–177.

[44] R. Klingenberg, C.E. Brokopp, A. Grivès, A. Courtier, M. Jaguszewski, N. Pasqual, E. Vlaskou Badra, A. Lewandowski, O. Gaemperli, S.P. Hoerstrup, W. Maier, U. Landmesser, T.F. Lüscher, C.M. Matter, Clonal restriction and predominance of regulatory T cells in coronary thrombi of patients with acute coronary syndromes, Eur. Heart J. 36 (17) (2015) 1041–1048.

[45] J.S. Hochman, L.A. Sleeper, J.G. Webb, T.A. Sanborn, H.D. White, J.D. Talley, C.E. Buller, A.K. Jacobs, J.N. Slater, J. Col, S.M. McKinlay, M.H. Picard, M.A. Menegus, J. Boland, V. Dzavik, C.R. Thompson, S.C. Wong, R. Steingart, R. Forman, P.E. Aylward, E. Godfrey, P. Desvigne-Nickens, T.H. LeJemtel, Early revascularization in acute myocardial infarction complicated by cardiogenic shock. SHOCK Investigators. Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock, N. Engl. J. Med. 341 (9) (1999) 625–634.

[46] J.H. Alexander, H.R. Reynolds, A.L. Stebbins, et al., Effect of tilarginine acetate in patients with acute myocardial infarction and cardiogenic shock: the TRIUMPH randomized controlled trial, JAMA 297 (2007) 1657–1666.

[47] H. Thiele, U. Zeymer, F.-J. Neumann, M. Ferenc, H.-G. Olbrich, J. Hausleiter, G. Richardt, M. Hennersdorf, K. Empen, G. Fuernau, S. Desch, I. Eitel, R. Hambrecht, J. Fuhrmann, M. Böhm, H. Ebelt, S. Schneider, G. Schuler, K. Werdan, Intraaortic balloon support for myocardial infarction with cardiogenic shock, N. Engl. J. Med. 367 (14) (2012) 1287–1296.

[48] J.A. Goldstein, D. Demetriou, C.L. Grines, M. Pica, M. Shoukfeh, W.W. O'Neill, Multiple complex coronary plaques in patients with acute myocardial infarction, N. Engl. J. Med. 343 (13) (2000) 915–922.

[49] M.D. Guazzi, M. Bussotti, L. Grancini, N. De Cesare, M. Guazzi, I.L. Pera, A. Loaldi, Evidence of multifocal activity of coronary disease in patients with acute myocardial infarction, Circulation 96 (4) (1997) 1145–1151.

[50] S. Halvorsen, I. Seljeflot, T. Weiss, E. Bøhmer, H. Arnesen, Inflammatory and thrombotic markers in patients with ST-elevation myocardial infarction treated with thrombolysis and early PCI: a NORDISTEMI substudy, Thromb. Res. 130 (3) (2012) 495–500.

[51] B.E.P.M. Claessen, R.J. van der Schaaf, N.J. Verouden, N.K. Stegenga, A.E. Engstrom, K.D. Sjauw, W.J. Kikkert, M.M. Vis, J. Baan, K.T. Koch, R.J. de Winter, J. G.P. Tijssen, J.J. Piek, J.P.S. Henriques, Evaluation of the effect of a concurrent chronic total occlusion on long-term mortality and left ventricular function in patients after primary percutaneous coronary intervention, JACC Cardiovasc. Interv. 2 (11) (2009) 1128–1134.

[52] L.P. Hoebers, B.E. Claessen, J. Elias, G.D. Dangas, R. Mehran, J.P.S. Henriques, Meta-analysis on the impact of percutaneous coronary intervention of chronic total occlusions on left ventricular function and clinical outcome, Int. J. Cardiol. 187 (2015) 90–96.

[53] D.A. Jones, R. Weerackody, K. Rathod, J. Behar, S. Gallagher, C.J. Knight, A. Kapur, A.K. Jain, M.T. Rothman, C.A. Thompson, A. Mathur, A. Wragg, E.J. Smith, Successful recanalization of chronic total occlusions is associated with improved long-term survival, JACC Cardiovasc. Interv. 5 (4) (2012) 380–388.

[54] K.R. Bainey, T. Engstrøm, P.C. Smits, A.H. Gershlick, S.K. James, R.F. Storey, D.A. Wood, R. Mehran, J.A. Cairns, S.R. Mehta, Complete vs Culprit-Lesion-Only Revascularization for ST-Segment Elevation Myocardial Infarction A Systematic Review and Meta-analysis, JAMA Cardiol. 5 (8) (2020) 881, https://doi.org/10.1001/jamacardio.2020.1251.

[55] V. Atti, Y. Gwon, M.A. Narayanan, S. Garcia, Y. Sandoval, E.S. Brilakis, M.B. Basir, M.K. Turagam, A. Khandelwal, C. Mena-Hurtado, M.A. Mamas, J.D. Abbott, D.L. Bhatt, P. Velagapudi, Multivessel Versus Culprit-Only Revascularization in STEMI and Multivessel Coronary Artery Disease Meta-Analysis of Randomized Trials, JACC-Cardiovas. Interv. 13 (13) (2020) 1571–1582.

[56] Y. Ahmad, J.P. Howard, A. Arnold, M. Prasad, H. Seligman, C.M. Cook, T. Warisawa, M. Shun-Shun, Z. Ali, M.A. Parikh, R. Al-Lamee, S. Sen, D. Francis, J. W. Moses, M.B. Leon, G.W. Stone, D. Karmpaliotis, Complete Revascularization by Percutaneous Coronary Intervention for Patients With ST-Segment-Elevation Myocardial Infarction and Multivessel Coronary Artery Disease: An Updated Meta-Analysis of Randomized Trials, J. Am. Heart Assoc. 9 (12) (2020), https://doi.org/10.1161/JAHA.119.015263.

[57] U.K. Allahwala, S.S. Jolly, V. Džavík, J.A. Cairns, S. Kedev, K. Balasubramanian, G. Stankovic, R. Moreno, N. Valettas, O. Bertrand, S. Lavi, J.L. Velianou, T. Sheth, B. Meeks, E.S. Brilakis, R. Bhindi, The Presence of a CTO in a Non-Infarct-Related Artery During a STEMI Treated With Contemporary Primary PCI Is Associated With Increased Rates of Early and Late Cardiovascular Morbidity and Mortality: The CTO-TOTAL Substudy, JACC Cardiovasc. Interv. 11 (7) (2018) 709–711.

[58] J.M. Larsen, J. Ravkilde, Acute coronary angiography in patients resuscitated from out-of-hospital cardiac arrest–a systematic review and meta-analysis, Resuscitation 83 (12) (2012) 1427–1433.

[59] C.G. Hanratty, Y. Koyama, H.H. Rasmussen, G.I.C. Nelson, P.S. Hansen, Cardiology MRWJJotACo, Exaggeration of nonculprit stenosis severity during acute myocardial infarction: implications for immediate multivessel revascularization, J. Am. Coll. Cardiol. 40 (2002) 911–916.

[60] R. Kornowski, R. Mehran, G. Dangas, E. Nikolsky, A. Assali, B.E. Claessen, B.J. Gersh, S.C. Wong, B. Witzenbichler, G. Guagliumi, D. Dudek, M. Fahy, A.J. Lansky, G.W. Stone, Prognostic impact of staged versus "one-time" multivessel percutaneous intervention in acute myocardial infarction: analysis from the HORIZONS-AMI (Harmonizing Outcomes with Revascularization and Stents in Acute Myocardial Infarction) trial, J. Am. Coll. Cardiol. 58 (7) (2011) 704–711.

[61] A.H. Gershlick, J.N. Khan, D.J. Kelly, J.P. Greenwood, T. Sasikaran, N. Curzen, D.J. Blackman, M. Dalby, K.L. Fairbrother, W. Banya, D. Wang, M. Flather, S.L. Hetherington, A.D. Kelion, S. Talwar, M. Gunning, R. Hall, H. Swanton, G.P. McCann, Randomized trial of complete versus lesion-only revascularization in patients undergoing primary percutaneous coronary intervention for STEMI and multivessel disease: the CvLPRIT trial, J. Am. Coll. Cardiol. 65 (10) (2015) 963–972.

[62] M.R. Patel, G.J. Dehmer, J.W. Hirshfeld, P.K. Smith, J.A. Spertus, F.A. Masoudi, G. J. Dehmer, M.R. Patel, P.K. Smith, C.E. Chambers, T.B. Ferguson, M.J. Garcia, F.L. Grover, D.R. Holmes, L.W. Klein, M.C. Limacher, M.J. Mack, D.J. Malenka, M.H. Park, M. Ragosta, J.L. Ritchie, G.A. Rose, A.B. Rosenberg, A.M. Russo, R.J. Shemin, W.S. Weintraub, M.J. Wolk, S.R. Bailey, P.S. Douglas, R.C. Hendel, C.M. Kramer, J. K. Min, M.R. Patel, L. Shaw, R.F. Stainback, J.M. Allen, ACCF/SCAI/STS/AATS/AHA/ASNC/HFSA/SCCT 2012 appropriate use criteria for coronary revascularization focused update: a report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, Society for Cardiovascular Angiography and Interventions, Society of Thoracic Surgeons, American Association for Thoracic Surgery, American Heart Association, American Society of Nuclear Cardiology, and the Society of Cardiovascular Computed Tomography, J. Thorac. Cardiovasc. Surg. 143 (4) (2012) 780–803.