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

A B S T R A C T

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; I² = 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; I² = 54.0%), all-cause mortality (OR: 2.89; 95% CI: 2.09–4.00; I² = 0.0%), cardiac death (OR: 3.12; 95% CI: 2.05–4.75; I² = 16.8%), heart failure (OR: 1.99; 95% CI: 1.22–3.24; I² = 0.0%), and stroke (OR: 2.80; 95% CI: 1.04–7.53; I² = 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.

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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], CyPRIST [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 I² statistic [15] with I² < 25% considered low, 25–75% moderate, and I² > 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-
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 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.

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; I² = 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; I² = 68.6%) or long-term follow-up (OR: 1.05; 95% CI: 0.80–1.37; I² = 77.8%; Fig. 2B). The risk of reinfarction 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; I² = 0.0%) or long-term follow-up (OR: 0.88; 95% CI: 0.51–1.51; I² = 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

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.

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| 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 |
|-------------------|--------------|-------------|--------------|-------------------------------------------------|-------------------------------|-------------------|---------------------|----------|
| 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/m² 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/m² | 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 vasoressors 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/m², 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 vasoressors 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 |
| Zeyner [25] 2015 | 2008–2011 | 562 173 | Multicenter, retrospective | Multicenter, prospective, inverse probability of treatment weighting | SBP < 90 mm Hg, heart rate > 100 beats/min, and end organ hypoperfusion 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) | 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 | Multicenter, prospective, inverse probability of treatment weighting | SBP < 90 mm Hg, heart rate > 100 beats/min, and end organ hypoperfusion | LM disease, prior CABG | All-cause death, cardiac death, MI, revascularization, MACE | 194 days |
| 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 |
|--------------|------|--------------|-------------|-------------|-----------------------------------------------|-------------------------------|-------------------|---------------------|----------|
| Hambraeus [27] | 2016 | 2006–2010 | 263 67 | Multicenter, prospective | NA | 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 | 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 with > 70% stenosis | SBP < 90 mm Hg for > 30 min or catecholamines required to maintain BP > 90 mm Hg; clinical signs of pulmonary congestion; signs of impaired organ perfusion with at least one of the following: altered mental status, cold—clammy skin and extremities, oliguria with urine output < 30 mL/hr, serum lactate > 2.0 mmol/L | 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 | 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 | 1 year |
| Thiele [18] | 2018 | 2013–2018 | 344 341 | Multicenter, randomized, open-label | ≥2 major vessels (≥2 mm in diameter) with > 70% stenosis | Resuscitation > 30 min, no intrinsic heart action, severe deficits in cerebral function, indication for primary CABG, shock > 12 h before randomization, age > 90 years, shock with a noncardiogenic cause, pulmonary embolism, pulmonary insufficiency, life expectancy < 6 months | Composite of all-cause death or severe renal failure, all-cause death, MI, revascularization, heart failure | 1 year |
| Lee [20] | 2019 | 2011–2015 | 399 260 | Multicenter, prospective | ≥1 major non-IRA or LM with ≥ 50% stenosis. | >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 | 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 | In-hospital mortality and acute kidney injury | In-hospital |

(continued on next page)
| 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 |
|-------------|------|--------------|-------------|-------------|-----------------------------------------------|-------------------------------|-----------------|---------------------|----------|
| First Author | Year | Study Period | Sample Size | 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 or with or without retrograde filling through collateral vessels | 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 rehospitalization 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 or retrograde filling through collateral vessels | Final diameter stenosis < 30% with a TIMI flow grade 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 antegrade or retrograde filling through collateral vessels | TIMI ≥ 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 ≥ 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 ≥ 3 months | Angiographic residual stenosis of <30% in the presence of TIMI grade 3 | Hemodynamically unstable, allergies to antplatelet 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 Author/Year | Group       | Group Description | Age(years) | Male(%) | Hypertension (%) | Hyperlipidemia (%) | Diabetes (%) | Smoking (%) | Heart rate(beats/min) | SBP(mm Hg) | LVEF | Three vessel disease (%) |
|-------------------|-------------|-------------------|------------|---------|------------------|-------------------|--------------|-------------|-----------------------|------------|------|--------------------------|
| Cavender [17]     | 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] | CO-PCIMV-PCI |                  | 67.4 ± 11.467.3 ± 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]        | CO-PCIMV-PCI |                  | 65.4 ± 12.267.2 ± 12.2 | 6871     | 6760             | 5547              | 3540         | 5455         | NA                    | NA         | NA   | 4651                      |
| Cavender [23]     | CO-PCIMV-PCI |                  | 66 ± 13.163 ± 14        | 6272     | 7972             | 2416              | 3135         | 7167         | 85 ± 2194.27          | 107 ± 2610.63 | 32 ± 1424.9 | 5251                      |
| Mylötte [21]      | CO-PCIMV-PCI |                  | 68.5 ± 11.865 ± 12.4   | 71.975.8 | 48.553           | 40.845.5          | 25.225.8     | 31.134.8     | 98 ± 21295 ± 20       | 83 ± 21282 ± 15.7 | 30.3 ± 931.9 | 47.651.5                   |
| Jaguszewski [19]  | CO-PCIMV-PCI |                  | 65.4 ± 11.267.4 ± 11.7 | 74.737.6 | 61.165.6         | 57.939.7          | 25.262.1     | 54.557.1     | NA                    | NA         | NA   | NA                       |
| Yang [24]         | CO-PCIMV-PCI |                  | 57.963.3               | 57.950   | 23.421.7         | 16.521.7          | 35.640.0     | 66.5 ± 32771.8 ± 35.2 | 83 ± 39876.6 ± 33.8 | 45.9 ± 13948.5 ± 15.3 | 44.267.4                   |
| Zeymer [25]       | CO-PCIMV-PCI |                  | 7172                  | 7881     | 6069             | 3539              | 3912         | NA           | NA                    | 6270        | NA   | NA                       |
| Park [26]         | CO-PCIMV-PCI |                  | 65.871                | 54.553.7 | 9.798            | 23.325.6          | 46.647.6     | 6266         | 8080                  | 50.3 ± 11.149.8 ± 15.3 | 39.946       | NA   | 51.325.4                  |
| Hambraeus [27]    | CO-PCIMV-PCI |                  | 71.3 ± 10.968 ± 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]       | CO-PCIMV-PCI |                  | 68 ± 12.669 ± 12.9    | 29.926.3 | 75.167.5         | 39.942.2          | 32.440.1     | 36.228.3     | 90 ± 2696 ± 27        | 92 ± 23972 ± 22 | 35 ± 14834 ± 13.7 | 6272.5                     |
| McNeece [29]      | CO-PCIMV-PCI |                  | 75.457.3              | 58.659.5 | 41.646.5         | 29.934.6          | 27.419.1     | NA           | NA                    | 29.330.9    | NA   | NA                       |
| Thiele [18]       | CO-PCIMV-PCI |                  | 7070                  | 7069     | 61.735.5         | 36.320.9          | 25.8 ± 194.2 | 29.8 ± 224.8 | 26.7 ± 264.6          | 83 ± 21282 ± 15.7 | 30.3 ± 931.9 | 47.651.5                   |
| Lee [20]          | CO-PCIMV-PCI |                  | 67.3 ± 12.866.2 ± 12.4 | 74.973.5 | 54.652.3         | 36.446.9          | 40.9 ± 124.2 | 36.340.4     | 80.5 ± 14751 ± 13.2  | 33 ± 14751 ± 13.2 | 33.333.8 | NA                       |
| Petrovic [30]     | CO-PCIMV-PCI |                  | 89.352.1              | 50.609.0 | 32.119.4         | 28.630.3          | 21.435.4     | NA           | NA                    | 35.035.0    | NA   | NA                       |
| Lemor [31]        | CO-PCIMV-PCI |                  | 79.518.2              | NA       | NA               | NA               | 40.544.6     | NA           | NA                    | NA         | NA   | NA                       |
| Yang [32]         | CO-PCIMV-PCI |                  | 69 ± 10.666 ± 11      | 8282     | 7670             | 2220              | 3736         | 3739         | 127                   | 47 ± 546 ± 7      | 6568 | NA                       |
| SHJ [33]          | CO-PCIMV-PCI |                  | 83.378                | 39.645   | NA               | NA               | 12.8 ± 11.7  | 23.292.1     | 39.645                | 40.9 ± 11.7  | 6568 | NA                       |
| Valenti [34]      | CO-PCIMV-PCI |                  | 69 ± 1464 ± 10        | 7385     | 6755             | 4136              | 1517         | 3050         | 5.451                | 38 ± 1236 ± 11   | 4859 | NA                       |
| Choi [35]         | CO-PCIMV-PCI |                  | 67.5 ± 11.262 ± 12.9  | 66.269.4 | 57.154.7         | 64.362.9          | 34.432.9     | 35.134.7     | 9.753                 | 49.6 ± 14251 ± 13 | 4442 | NA                       |
| Henriques [36]    | CO-PCIMV-PCI |                  | 60 ± 10.606 ± 10      | 8289     | 4540             | 3435              | 1615         | 4952         | NA                    | 42 ± 1241 ± 11   | NA   | NA                       |
| Lee [37]          | CO-PCIMV-PCI |                  | 60.5 ± 9.359.4 ± 10.6 | 83.482.6 | 64.559.8         | 59.264.1          | 3231         | 23.127       | 4.719                 | 57.5 ± 8.577.8 ± 8.6 | 27.818.9 | NA                       |
| Deng [38]         | CO-PCIMV-PCI |                  | 68.7 ± 10.165 ± 10.1  | 78.879.2 | 73.778.3         | 73.180.5          | 28.233.9     | 51.958.8     | NA                    | 50.1 ± 9.449.3 ± 10.8 | 32.733.3 | NA                       |
| Park [39]         | CO-PCIMV-PCI |                  | 65 ± 12.464 ± 11.3    | 71.370.7 | 51.564.2         | 29.726.8          | 37.639.3     | 52.550.5     | NA                    | 57.451.1    | NA   | NA                       |

(continued on next page)
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; I² = 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; I² = 0.0%; Fig. 4B). The risks of long-term re-infarction (OR: 1.69; 95% CI: 0.96–2.98; I² = 0.0%; Fig. 4D) and revascularization (OR: 1.16; 95% CI: 0.57–2.35; I² = 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; I² = 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; I² = 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; I² = 0.0%; Fig. 5E), without significant differences in bleeding (OR: 0.38; 95% CI: 0.07–1.97; I² = NA; Fig. 5C) and re-infarction (OR: 1.69; 95% CI: 0.96–2.98; I² = 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.
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. 2. Forest Plot of Primary 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-

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**Fig. 3.** Forest Plot of Secondary and Safety Outcomes in Patients Complicated by Cardiogenic Shock Treated with Immediate 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.
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

| Study ID | OR (95% CI) | Events, CO-PCI | Events, MV-PCI | Weight |
|----------|-------------|---------------|---------------|--------|
| A Long-term Cardiac Death | | | | |
| Yang (2013) | 2.93 (1.04, 8.28) | 10/49 | 7/87 | 13.77 |
| Shi (2014) | 3.01 (1.15, 7.85) | 11/48 | 9/100 | 15.68 |
| Valenti (2014) | 7.56 (0.96, 59.32) | 13/111 | 1/58 | 3.98 |
| Choi (2016) | 3.04 (1.53, 6.06) | 31/154 | 13/170 | 25.95 |
| Henriques (2016) | 0.10 (0.01, 1.95) | 0/154 | 4/148 | 2.01 |
| Deng (2016) | 4.84 (2.11, 11.09) | 24/158 | 8/221 | 19.80 |
| Park (2018) | 2.60 (1.11, 6.13) | 10/101 | 13/321 | 18.81 |

### Long-term Heart Failure

| Study ID | OR (95% CI) | Events, CO-PCI | Events, MV-PCI | Weight |
|----------|-------------|---------------|---------------|--------|
| Yang (2013) | 2.23 (0.76, 6.58) | 6/49 | 7/87 | 20.32 |
| Shi (2014) | 3.01 (1.15, 7.85) | 11/48 | 9/100 | 25.80 |
| Deng (2016) | 1.56 (0.80, 3.04) | 20/156 | 19/221 | 53.88 |

### Long-term Bleeding

| Study ID | OR (95% CI) | Events, CO-PCI | Events, MV-PCI | Weight |
|----------|-------------|---------------|---------------|--------|
| Henriques (2016) | 0.38 (0.07, 1.97) | 2/154 | 5/148 | 100.00 |

### Long-term Re-infarction

| Study ID | OR (95% CI) | Events, CO-PCI | Events, MV-PCI | Weight |
|----------|-------------|---------------|---------------|--------|
| Yang (2013) | 0.58 (0.02, 14.57) | 0/49 | 1/87 | 3.11 |
| Shi (2014) | 1.44 (0.48, 4.32) | 6/48 | 9/100 | 26.83 |
| Valenti (2014) | 0.52 (0.03, 8.44) | 1/111 | 1/58 | 4.14 |
| Choi (2016) | 4.60 (0.96, 22.02) | 8/154 | 2/170 | 13.15 |
| Henriques (2016) | 0.57 (0.13, 2.42) | 3/154 | 5/148 | 15.33 |
| Deng (2016) | 2.41 (0.57, 10.22) | 5/156 | 3/221 | 15.40 |
| Park (2018) | 2.73 (0.82, 9.16) | 5/101 | 6/321 | 22.05 |

### Long-term Stroke

| Study ID | OR (95% CI) | Events, CO-PCI | Events, MV-PCI | Weight |
|----------|-------------|---------------|---------------|--------|
| Shi (2014) | 1.41 (0.23, 8.70) | 2/48 | 3/100 | 29.47 |
| Valenti (2014) | 2.13 (0.23, 19.52) | 4/111 | 1/58 | 19.97 |
| Choi (2016) | 4.60 (0.96, 22.02) | 8/154 | 2/170 | 39.99 |
| Henriques (2016) | 4.87 (0.23, 102.27) | 2/154 | 0/148 | 10.57 |

NOTE: Weights are from random effects analysis

Fig. 5. Forest Plot of Secondary and Safety Outcomes in Patients Complicated by CTO Treated with Staged MV-PCI or CO-PCI Strategy.
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/m² (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). 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 toler-
Five-Year Planning Project of the Scientific and Technological Department of China (2011BA11B02).

Appendix A. Supplementary data

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

References

[1] B.E. Jaski, J.D. Cohen, J. Trausch, D.G. Marsh, C. Samosir, P. Overlie, E.W. J.M. Lee, T.M. Rhee, H.K. Kim, et al., Comparison of Long-Term Clinical Outcome among Primary Angioplasty and Coronary Bypass Surgery for Native Coronary Artery Disease: A Randomized Trial, J. Am. Coll. Cardiol. 51 (2008) 547–555.

[2] D.S. Wald, M.J. Morris, N.J. Wald, A.J. Chase, R.J. Edwards, L.H. Hughes, C. Berry, K.G. Oldroyd, Randomized trial of preventive angioplasty in myocardial infarction, N. Engl. J. Med. 359 (12) (2013) 1115–1123.

[3] 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 CvPRT trial, J. Am. Coll. Cardiol. 65 (2015) 963–972.

[4] T. Engstrøm, H. Kelbaek, S. Helqvist, L. Kløvgaard, L. Holmvang, E. R. Valenti, M. Marrani, G. Cantini, A. Migliorini, N. Carrabba, R. Vergara, G. Cerisano, A. Reyentovich, M.H. Barghash, J.S. Hochman, Management of refractory angina in acute myocardial infarction complicated by cardiogenic shock: the role of primary multivessel revascularization, JACC Cardiovasc. Interv. 9 (2016) 115–125.

[5] I.Y. Elgendy, T. Huo, A. Mahmoud, A.A. Bavry, Complete versus culprit-only percutaneous coronary intervention in ST-elevation myocardial infarction: is more or less, EuroIntervention 9 (8) (2013) 909–915.

[6] J.M. Lee, T.M. Rhee, H.K. Kim, et al., Comparison of Long-Term Clinical Outcome Between Multivessel PCI and Single Vessel PCI: The Outcomes-Oriented Percutaneous Coronary Intervention – Related Artery Only-Revascularization for Patients With ST-Segment Elevation Myocardial Infarction, J. Am. Heart Assoc. 8 (2019) e013870.

[7] D. Mylotte, M.-C. Monceau, H. Elchaninoff, 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 (2013) 115–125.

[8] 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: the EHS-PCI Registry, Am. J. Cardiol. 109 (7) (2012) 941–946.

[9] M.A. Cavender, J. Rajeswaran, L. DiPaola, et al., Outcomes of culprit versus non-culprit PCI in patients with multivessel PCI, JACC Cardiovasc. Interv. 25 (2012) 2240–2247.

[10] J.H. Yang, J.-Y. Hahn, P.S. Yong, B.Y. Song, S.-H. Choi, J.-H. Lee, S.H. Moon, J.-M. Jeong, D.-J. Choi, Y.J. Kim, H.-C. Gwon, Percutaneous coronary intervention for non-culprit vessels in culprit PCI in patients with acute myocardial infarction presenting with ST-elevation myocardial infarction complicated by shock, J. Invasive Cardiol. 25 (2013) 224–230.

[11] 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.

[12] 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 PCI in terms of long-term outcome in patients with acute myocardial infarction complicated by cardiogenic shock, Heart 101 (15) (2015) 1225–1232.

[13] K. Hambraeus, K. Jensevik, B. O Lagerqvist, B. Lindahl, R. Carlsson, F. Farzaneh-Far, T. Kellert, E. Omerovic, G. Stone, C. Varenhorst, J. 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.

[14] U. Zeymer, K. Wedran, G. Schuler, R. Zahn, F. Neumann, S. 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 ALKK-PCI Registry, EuroIntervention 11 (2015) b2700.

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

[16] A. Lemor, M. Basir, K. Patel, et al., TCT-813 Culprit-Vessel Versus Multivessel Percutaneous Coronary Intervention in Cardiogenic Shock: insights from the 2018 Washington Columbia Cardiac Registry, Catheteriz. Cardiovasc. Interv. (2018) (no pagination).

[17] R. Valet, M. Marrani, G. Cantini, A. Migliorini, N. Carrabba, R. Vergara, G. Cerisano, G. Campo, S. De Waha, L. Al-Khalaf, D. Antoniou, C. Skurk, S. Schneider, H. Thiele, Editor’s Choice: Impact of immediate multivessel percutaneous coronary intervention versus culprit lesion intervention on one-year outcome in patients treated with primary percutaneous coronary intervention for coronary shock, Am. J. Cardiol. 105 (7) (2010) 955–959.

[18] R. Elsässer, A. Gitt, R. Zahn, Immediate multivessel PCI in patients with acute myocardial infarction complicated by cardiogenic shock, Crit. Care Med. 42 (1) (2014) 17–25.

[19] 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 PCI in terms of long-term outcome in patients with acute myocardial infarction complicated by cardiogenic shock, Heart 101 (15) (2015) 1225–1232.

[20] G. Shi, P. He, Y. Liu, Y. Lin, X. Yang, J. Chen, Y. Zhou, N. Tan, Evaluation of the effect of concurrent total coronary occlusion and treatment in patients with STE-Segment elevation myocardial infarction, Sci. World J. 2014 (2014) 1–9.

[21] Z.K. Yang, R.Y. Zhang, H. Ju, Q. 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.

[22] G. Shi, P. He, Y. Liu, Y. Lin, X. Yang, J. Chen, Y. Zhou, N. Tan, Evaluation of the effect of concurrent total coronary occlusion and treatment in patients with STE-Segment elevation myocardial infarction, Sci. World J. 2014 (2014) 1–9.

[23] I.J. Choi, Y.-S. Koh, S. Lim, E.H. Choo, J.J. Kim, B.-H. Hwang, T.-H. Kim, M.S. Lee, S.J. Kang, M.-W. Park, C.J. Kim, J. Roh, S.-H. Lee, H.-G. Kim, J.-M. Lee, J.K. Lee, S.-B. Kang, S.-H. Lim, J.-H. Lee, B.-H. Hwang, J.I. Lee, K.-M. 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 Data Registry), Am. J. Cardiol. 117 (2016) 1039–1046.
