The effect of complete revascularization in patients with ST-segment elevation myocardial infarction with Killip class ≥ III

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Background: The effect of complete revascularization (CR) on high-risk patients with ST-segment elevation myocardial infarction (STEMI) has remains a controversial issue, especially on patients in a critical condition. The aim of this study was to explore the effect of CR on patients with STEMI with Killip class ≥ III.

Methods: From January 2008 to December 2014, 185 patients diagnosed with STEMI with Killip class ≥ III and multiple vessel coronary artery disease received primary percutaneous coronary intervention (PCI). Eighty-nine patients underwent culprit-only PCI, and the remaining 96 patients underwent immediate or staged PCI for CR. Out of the 96 patients in the CR group, 51 patients underwent immediate CR, and 45 patients underwent CR during the same hospitalization. Thirty-day and 1-year clinical outcomes were compared between the culprit-only PCI group and the CR group as well as between the immediate CR group and staged CR group.

Results: There was a trend toward a lower incidence of post-PCI acute kidney injury in the culprit-only PCI group when compared with the CR group (14.8% vs. 26.0%; *P* = 0.069). Thirty-day and 1-year cardiovascular mortality and all-cause mortality were similar between the culprit-only

PCI group and CR group. Decreased 1-year cardiovascular mortality and all-cause mortality were noted in the staged CR group compared with the immediate CR group.

Conclusion   CR was associated a higher possibility of post-PCI acute kidney injury and did not seem to improve 30-day or 1-year clinical outcomes. Patients undergoing staged CR during the same hospitalization had better clinical outcomes. *Coron Artery Dis* 31: 13–19 Copyright © 2019 The Author(s). Published by Wolters Kluwer Health, Inc.

Introduction

It is increasingly common for patients who experienced ST-segment elevation myocardial infarction (STEMI) to be diagnosed with multivessel coronary artery disease (MVD). Patients with MVD have a relatively poor prognosis [1]. The optimal management protocol for patients with STEMI and MVD remains controversial. Currently, American College of Cardiology/American Heart Association guidelines suggests a class IIb recommendation (Level of Evidence B) for multivessel percutaneous coronary intervention (PCI), which can be treated by either as a single- or multi-stage procedure in STEMI patients [2]. The European Society of Cardiology provides Class IIa recommendation (Level of Evidence A) of routine revascularization for non-infarct related artery

lesions and states that it should be considered in STEMI patients with MVD before hospital discharge [3]. Despite these guidelines, physicians need to consider the importance of individualizing care for each patient, balancing the anticipated benefits from multi-vessel PCI against its potential risks, especially in high-risk patients.

In patients with STEMI of the anterior wall, Killip class ≥ III, high serum levels of cardiac biomarker, and high global registry of acute coronary events risk scores are the risk factors for in-hospital and long-term prognoses [4]. Previous studies had demonstrated favorable outcomes in patients with STEMI and MVD who underwent multi-vessel PCI, but the study groups only included relatively stable patients [5–8]. On the other hand, cardiogenic shock is an important and serious complication of STEMI. Multi-vessel PCI performed at the time of primary PCI in patients with cardiogenic shock and MVD is generally considered an acceptable management strategy. However, one meta-analysis and the culprit lesion only

PCI versus multivessel PCI in cardiogenic shock study did not support multi-vessel PCI for STEMI patients with cardiogenic shock [9,10]. Therefore, the outcome of complete revascularization in relatively stable patients and high-risk patients may be different. However, few studies have focused on STEMI patients in relatively critical condition. Therefore, we aimed to explore the effect of complete revascularization on high-risk patients with STEMI of Killip class ≥ III.

Materials and methods
Patients and groups
From January 2008 to December 2014, 185 patients were diagnosed with STEMI of Killip ≥ III and with MVD at our hospital. The patients who underwent coronary artery bypass graft for revascularization, had only one-vessel coronary artery disease, or with less than 70% stenosis of the non-culprit vessel were excluded. All charts were reviewed retrospectively. According to the different strategy of PCI, 89 patients were enrolled into the culprit-only PCI group, and 96 patients were enrolled into the complete revascularization group. In the complete revascularization group, 51 patients underwent multi-vessel PCI immediately and 45 patients underwent staged PCI during the same hospitalization.

The Institutional Review Committee on Human Research of our institution approved the study protocol.

Definitions
Definition of the myocardial infarction (MI) is in accordance with the most recent universal definition of MI [11]. Killip III describes individuals with frank acute pulmonary edema and Killip class IV describes individuals in cardiogenic shock or hypotension (measured as systolic blood pressure lower than 90 mmHg) and with evidence of peripheral vasoconstriction (oliguria, cyanosis, or sweating) [12]. Acute kidney injury (AKI) is defined as either an increase in serum creatinine concentration by ≥0.5 mg/dl compared to the admission value or a ≥25% relative rise in the serum creatinine concentration during the first 72 hours after the procedure [13]. Cardiovascular mortality is defined as death related to MI, cardiac arrhythmia, and heart failure. All-cause mortality is defined as death from any causes, including cardiovascular mortality, stroke, and sepsis.

Study endpoints
The primary endpoints of our study were 30-day cardiovascular mortality and all-cause mortality. The secondary endpoints were 1-year cardiovascular mortality and all-cause mortality.

Statistical analysis
Data were expressed as a mean ± SD for continuous variables, as counts and percentages for categorical variables and as median and interquartile range for non-normally distributed parameters. Continuous variables were compared using an independent samples t-test or Mann–Whitney U tests. Categorical variables were compared using a Chi-square statistic or the Kruskal–Wallis test. Univariate Cox regression analyses about 30-day cardiovascular mortality and 1-year cardiovascular mortality were performed to identify the impact of complete revascularization for the whole study population and different subgroups. Kaplan–Meier curves were plotted for 30-day cardiovascular mortality among all patients and in specific groups. Statistical analyses were performed using SPSS 22.0 (IBM Corp., Armonk., New York, USA). A P-value less than 0.05 was considered statistically significant.

Results
Baseline characteristics
(Table 1) The average age of the culprit-only PCI group was 64.0 ± 12 years, and 77.5% were male. The average age of the complete revascularization group was 65.0 ± 13 years and 77.1 % were male. There was no significant difference in age or gender in these groups or between immediate complete revascularization and staged complete revascularization groups. Higher BMI was noted in the staged complete revascularization group when compared with the immediate complete revascularization group. There was no significant difference in prevalence of smoking, diabetes mellitus, hypertension, prior history of MI, prior history of stroke, and end-stage renal disease between culprit-only PCI group and complete revascularization group or between immediate complete revascularization group and staged complete revascularization group. Chest pain to emergency department transit time and reperfusion time was not significantly different between culprit-only PCI group and complete revascularization group or between immediate complete revascularization group and staged complete revascularization group. Within the complete revascularization group, a higher prevalence of anterior wall involvement was found in the immediate complete revascularization group when compared with the staged complete revascularization group (82.4% vs. 31.1%; $P < 0.001$). The prevalence of left main disease was a little higher in the complete revascularization group (vs. culprit only PCI) and immediate complete revascularization (vs. staged) groups but it was not statistically significant. Higher prevalence of extra-corporeal membrane oxygenation (ECMO) support was noted in the immediate complete revascularization group but did not reach statistically significant difference when compared with the staged complete revascularization group. Less frequent beta-blocker use was noted in the immediate complete revascularization group when compared with the staged complete revascularization group (47.1% vs. 71.1%; $P = 0.047$). A trend towards reduced post-PCI AKI in culprit-only PCI group was found when compared with the complete revascularization group (14.8% vs. 26.0%; $P = 0.069$), and no difference was found in the incidence of post-PCI

Table 1 Baseline characteristics of patients with culprit-only percutaneous coronary intervention versus complete revascularization

	Culprit-only PCI (N=89)	CR			P-value (culprit-only PCI vs. CR)	P-value (immediate vs. staged)
		All (N=96)	Immediate (N=51)	Staged (N=45)		
General demographics						
Age (years)	64.0 ± 12	65.0 ± 13	66.9 ± 13	62.4 ± 13	0.654	0.087
Male sex (%)	69 (77.5)	74 (77.1)	40 (78.4)	34 (75.6)	0.568	0.810
Risk factors for MI						
BMI (kg/m²)	25.96 ± 3.51	25.54 ± 4.33	24.56 ± 4.24	26.51 ± 4.23	0.492	0.033
Current smoker (%)	46 (51.7)	49 (51.0)	27 (52.9)	22 (48.9)	1.000	0.838
Diabetes mellitus (%)	44 (49.4)	52 (54.2)	29 (56.9)	23 (51.1)	0.558	0.682
Hypertension (%)	60 (67.4)	63 (65.6)	35 (68.6)	28 (62.2)	0.876	0.527
Prior MI (%)	9 (10.1)	11 (11.5)	7 (13.7)	4 (8.9)	0.816	0.534
Prior stroke (%)	10 (11.2)	17 (17.7)	8 (15.7)	9 (20.0)	0.297	0.604
ESRD on maintenance hemodialysis (%)	4 (4.5)	3 (3.1)	1 (2.0)	2 (4.4)	0.712	0.598
The severity of MI						
SBP (mmHg)	109.43 ± 41.34	111.21 ± 41.02	111.29 ± 39.98	111.11 ± 42.66	0.769	0.983
Killip IV (%)	62 (69.7)	65 (67.7)	34 (66.7)	31 (68.9)	0.874	0.831
Timing of primary PCI						
Chest pain-to-ER time (minutes)	170.79 ± 79.11	212.58 ± 40.28	201.60 ± 18.74	224.46 ± 64.15	0.223	0.679
Reperfusion time (minutes)	24.37 ± 5.40	22.65 ± 2.65	24.63 ± 4.80	20.43 ± 9.40	0.409	0.110
Laboratory examination						
White blood cell count (×103)	12.6 ± 4.4	13.0 ± 5.1	12.9 ± 5.2	13.0 ± 5.1	0.579	0.970
Blood fasting sugar (mg/dl)	191.83 ± 114.14	210.84 ± 107.62	208.07 ± 108.56	213.97 ± 107.90	0.284	0.807
HbA1C (%)	6.85 ± 1.40	7.37 ± 2.09	7.30 ± 2.02	7.44 ± 2.18	0.070	0.764
Creatinine (except ESRD) (mg/dl)	1.64 ± 1.21	1.61 ± 1.04	1.74 ± 1.14	1.46 ± 0.89	0.861	0.194
LDL-cholesterol (mg/dl)	101.27 ± 40.90	106.02 ± 43.78	106.51 ± 48.73	105.57 ± 39.17	0.473	0.922
HDL (mg/dl)	39.13 ± 11.69	41.06 ± 11.84	40.88 ± 12.40	41.23 ± 11.43	0.293	0.893
Peak Troponin-I (ng/ml)	81.48 ± 16.43	72.97 ± 13.79	72.43 ± 18.74	73.71 ± 16.85	0.539	0.919
LVEF (%)	49.86 ± 13.79	47.36 ± 15.89	44.33 ± 14.88	50.38 ± 16.45	0.282	0.071
Infarcted territory (%)					0.126	< 0.001
Anterior	41 (46.1)	56 (58.3)	42 (82.4)	14 (31.1)		
Inferior	43 (48.3)	37 (38.5)	8 (15.7)	29 (64.4)		
Lateral	2 (2.2)	3 (3.1)	1 (2.0)	2 (4.4)		
Posterior	3 (3.4)	0 (0)	-	-		
Characteristics of coronary artery disease						
Left main disease (%)	10 (11.2)	21 (21.9)	15 (29.4)	6 (13.3)	0.075	0.083
Non-infarcted vessel as CTO (%)	26 (29.2)	29 (27.6)	17 (33.3)	12 (26.7)	0.873	0.512
Procedural device						
IABP (%)	53 (59.6)	63 (65.6)	37 (72.5)	26 (57.8)	0.448	0.139
ECMO (%)	12 (13.5)	16 (16.7)	12 (23.5)	4 (8.9)	0.682	0.062
Post-MI Medications (%)						
ACEI/ARBs	60 (68.2)	73 (76.0)	37 (72.5)	36 (80.0)	0.252	0.476
Beta-blockers	55 (62.5)	56 (58.3)	24 (47.1)	32 (71.1)	0.559	0.047
Statins	45 (51.1)	59 (61.5)	29 (56.9)	30 (66.7)	0.181	0.402
Post-PCI acute kidney injury (%)	13 (14.8)	25 (26.0)	14 (27.5)	11 (24.4)	0.069	0.818

Data are expressed as mean ± SD or as number (percentage).
ACEI, angiotensin-converting-enzyme inhibitor; ARB, angiotensin II receptor blockers; BMI, body mass index; CR, complete revascularization; CTO, chronic total occlusion; ECMO, extra-corporeal membrane oxygenation; ER, emergent room; ESRD, end-stage renal disease; HbA1C, hemoglobin A1C; HDL, high-density lipoprotein; IABP, intra-aortic balloon pumping; LDL, low-density lipoprotein; LVEF, left ventricular ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; SBP, systolic blood pressure.

AKI between the immediate complete revascularization group and the staged complete revascularization group.

Culprit and non-culprit vessel angiography and method of primary percutaneous coronary intervention
(Table 2) When examining pre-PCI angiography, pre-PCI reference luminal diameter of culprit vessel was noted to be larger in the staged complete revascularization group when compared with the immediate complete revascularization group (2.88 ± 0.59 vs. 3.34 ± 0.67 mm; P = 0.001). Pre-PCI thrombolysis in myocardial infarction flow, pre-PCI stenotic percentage, and pre-PCI minimal luminal diameter of culprit vessel was not any different between the culprit-only PCI group and complete revascularization group or between the immediate complete revascularization group and staged complete revascularization group. When reviewing post-PCI angiography,

larger post-PCI reference luminal diameter of culprit vessel was noted in the staged complete revascularization group when compared with the immediate complete revascularization group (3.17 ± 0.55 vs. 3.46 ± 0.63 mm; P = 0.019). Post-PCI thrombolysis in myocardial infarction flow, post-PCI stenotic percentage, and post-PCI minimal luminal diameter of culprit vessel was not different between the culprit-only PCI group and complete revascularization group or between the immediate complete revascularization group and staged complete revascularization group. The ratio of bare-metal stent use to drug-eluting stent use was similar between the culprit-only PCI group and complete revascularization group or between the immediate complete revascularization group and staged complete revascularization group. The stenotic percentage of non-culprit vessel showed no difference between the culprit-only PCI group and

Table 2   Culprit and non-culprit vessel angiography and method of primary percutaneous coronary intervention

| | Culprit-only PCI (N=89) | CR | | | P-value (culprit-only PCI vs. CR) | P-value (immediate vs. staged) |
		All (N=96)	Immediate (N=51)	Staged (N=45)		
Culprit vessel						
Pre-PCI angiography						
Pre-PCI TIMI flow					0.500	0.650
≥ 2 (%)	20 (22.5)	26 (27.1)	15 (29.4)	11 (24.4)		
≤ 1 (%)	69 (77.5)	70 (72.9)	36 (70.6)	34 (75.6)		
Pre-PCI stenosis (%)	95.14 ± 8.87	94.32 ± 8.73	93.53 ± 9.37	95.22 ± 7.95	0.527	0.348
Pre-PCI MLD (mm)	0.13 ± 0.05	0.15 ± 0.04	0.16 ± 0.04	0.13 ± 0.05	0.672	0.489
Pre-PCI RLD (mm)	3.07 ± 0.71	3.08 ± 0.66	2.88 ± 0.59	3.34 ± 0.67	0.864	0.001
Post-PCI angiography						
Post-PCI TIMI flow					0.446	0.663
≥ 2 (%)	87 (97.8)	91 (94.8)	49 (96.1)	42 (93.4)		
≤ 1 (%)	2 (2.2)	5 (5.2)	2 (3.9)	3 (6.7)		
Post-PCI stenosis (%)	17.16 ± 11.22	16.52 ± 12.25	16.27 ± 9.94	16.80 ± 4.59	0.713	0.836
Post-PCI MLD (mm)	2.66 ± 0.56	2.75 ± 0.66	2.66 ± 0.58	2.85 ± 0.73	0.346	0.151
Post-PCI RLD (mm)	3.24 ± 0.58	3.31 ± 0.60	3.17 ± 0.55	3.46 ± 0.63	0.448	0.019
Method of PCI					1.000	0.790
Bare-metal stents (%)	73 (82.0)	79 (82.3)	41 (80.4)	38 (84.4)		
Drug-eluting stents (%)	16 (18.0)	17 (17.7)	10 (19.6)	7 (15.6)		
Non-culprit vessel						
Stenosis (%)	82.45 ± 12.26	84.27 ± 11.09	85.36 ± 11.58	83.24 ± 10.62	0.279	0.330

Data are expressed as mean ± SD or as number (percentage).
CR, complete revascularization; MLD, minimal luminal reference; PCI, percutaneous coronary intervention; RLD, reference luminal diameter; TIMI, thrombolysis in myocardial infarction.

Table 3   Thirty-day and 1-year clinical outcomes of patients with culprit-only percutaneous coronary intervention versus complete revascularization

| | Culprit-only PCI (N=89) | CR | | | P-value (culprit-only PCI vs. CR) | P-value (immediate vs. staged) |
		All (N=96)	Immediate (N=51)	Staged (N=45)		
30-day outcome						
Cardiovascular mortality (%)	16 (18.0)	14 (14.6)	10 (19.6)	4 (8.9)	0.551	0.155
All-cause mortality (%)	17 (19.1)	16 (16.7)	12 (23.5)	4 (8.9)	0.701	0.059
1-year outcome						
Cardiovascular mortality (%)	20 (23.3)	22 (23.2)	16 (31.4)	6 (13.3)	0.914	0.042
All-cause mortality (%)	24 (27.0)	31 (32.3)	23 (45.1)	8 (17.8)	0.498	0.003

Data are expressed as mean ± SD or as number (percentage).
CR, complete revascularization; PCI, percutaneous coronary intervention.

complete revascularization group (82.45 ± 12.26% vs. 84.27 ± 11.09%; $P = 0.279$) or between the immediate complete revascularization group and staged complete revascularization group (85.36 ± 11.58% vs. 83.24 ± 10.62%; $P = 0.330$).

Thirty-day and 1-year clinical outcomes of patients with culprit-only percutaneous coronary intervention versus complete revascularization

(Table 3) When the culprit-only PCI group was compared to complete revascularization group, there was a similar prevalence of 30-day cardiovascular mortality (18.0% vs. 14.6%; $P = 0.551$) and 30-day all-cause mortality (19.1% vs. 16.7%; $P = 0.701$) as well as 1-year cardiovascular mortality (23.3% vs. 23.2%; $P = 0.914$) and 1-year all-cause mortality (27.0% vs. 32.3%; $P = 0.498$).

In the complete revascularization group, a trend of lower 30-day cardiovascular mortality (19.6% vs. 8.9%; $P = 0.155$) and 30-day all-cause mortality (23.5% vs. 8.9%; $P = 0.059$) were noted in the staged complete revascularization group when compared to the immediate complete revascularization group. In addition, lower 1-year cardiovascular mortality (31.4% vs. 13.3%; $P = 0.042$) and 1-year all-cause mortality (45.1% vs. 17.8%; $P = 0.003$) were noted in the staged complete revascularization group when compared with the immediate complete revascularization group.

Univariate Cox regression analyses of complete revascularization and 30-day and 1-year cardiovascular mortality for whole study patients and different subgroups (Table 4).

Complete revascularization showed no significantly positive effect on the whole study population and different subgroups including the patients with Killip III status, Killip IV status, anterior wall involvement, non-culprit vessel as chronic total occlusion (CTO), intra-aortic balloon pumping support, and ECMO support.

The Kaplan–Meier curves of 30-day cardiovascular mortality in all groups, and subgroups

(Figs. 1 and 2) When comparing the culprit-only PCI group vs. the complete revascularization group or

comparing the culprit-only, immediate complete revascularization and staged complete revascularization groups, the Kaplan–Meier curve of 30-day cardiovascular mortality showed no significant differences (Fig. 1a and b).

There were similar outcomes in the Kaplan–Meier curve of 30-day cardiovascular mortality for the patients diagnosed with Killip III level MI, Killip IV level MI, anterior wall MI, non-culprit vessel as CTO, those who needed intra-aortic balloon pumping support, and those who received ECMO support (Fig. 2a through f).

Table 4   Univariate Cox regression analyses of complete revascularization and 30-day and 1-year cardiovascular mortality for whole study patients and different subgroups

| Variable	Hazard ratio	95% Confidence interval	*P*-value
For whole study patients			
30-day period	0.759	0.370–1.554	0.450
1-year period	0.990	0.540–1.814	0.973
For only Killip III patients			
30-day period	0.829	0.117–5.888	0.852
1-year period	1.698	0.424–6.795	0.455
For only Killip IV patients			
30-day period	0.768	0.355–1.662	0.503
1-year period	0.867	0.438–1.716	0.681
For anterior wall STEMI			
30-day period	0.938	0.395–2.227	0.885
1-year period	1.382	0.642–2.974	0.408
For non-culprit vessel as CTO			
30-day period	0.400	0.100–1.599	0.195
1-year period	0.793	0.050–12.680	0.870
For the patients with IABP support			
30-day period	0.889	0.406–1.948	0.769
1-year period	0.943	0.481–1.849	0.864
For the patients with ECMO support			
30-day period	0.769	0.223–2.657	0.678
1-year period	0.749	0.262–2.137	0.589

CTO, chronic total occlusion; ECMO, extra-corporeal membrane oxygenation; IABP, intra-aortic balloon pumping; STEMI, ST-segment elevation myocardial infarction.

Discussion

In our study, thirty-day and 1-year clinical outcomes were similar between the culprit-only and complete revascularization groups. A trend toward a high incidence of post-PCI AKI was noted in the complete revascularization group. Better 1-year clinical outcomes were noted in the staged complete revascularization group. In high-risk patients (including those with Killip IV, Killip III, anterior wall MI, non-culprit vessel as CTO, and mechanical support), complete revascularization did not improve 30-day cardiovascular mortality.

The patients with STEMI and MVD have multifactorial problems including pan-coronary inflammation, diffuse atherosclerosis with multiple unstable coronary plaques, and impaired contractility of non-infarct zones resulting from multiple coronary stenosis [14,15]. Complete revascularization at the time of primary PCI increases myocardial salvage by increasing perfusion to the watershed areas by relieving flow limitations of the non-infarct artery and stabilizing other bystander vulnerable plaques [16]. One meta-analysis report stated that multi-vessel PCI either during primary PCI or staged PCI results in lower occurrences of major adverse cardiovascular events, revascularization, and cardiovascular mortality than infarct-only PCI [17]. However, these studies only focused on relatively stable patients and excluded patients with mechanical support. In addition, multi-vessel PCI increases the possibility of post-PCI AKI due to increasing contrast volume, especially in the patients who are in critical condition and require mechanical support [7,8]. Staged PCI during a short-term interval was also associated with a higher incidence of post-PCI AKI in patients with anterior MI [18]. Caspi *et al.* noted that AKI was strongly associated with baseline renal function, age, heart failure, hemodynamic

Fig. 1
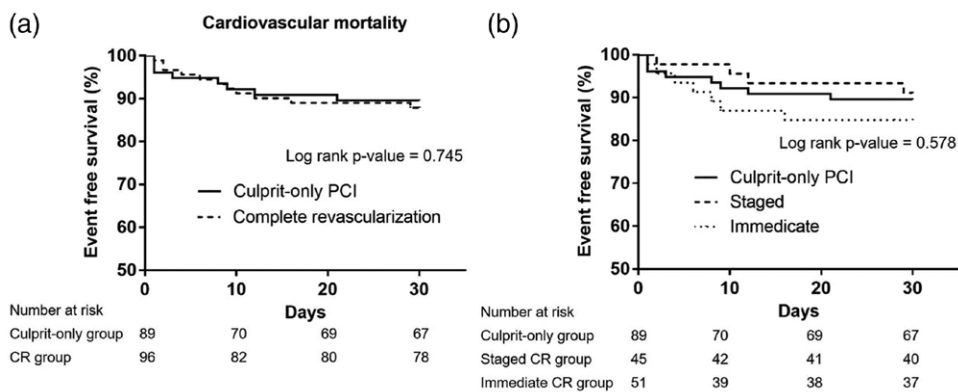
Kaplan–Meier curves of 30-day cardiovascular mortality. (a) Kaplan–Meier curve of 30-day cardiovascular mortality of culprit-only group and CR group: There was no difference between two groups (*P* = 0.745). (b) A Kaplan–Meier curve of 30-day cardiovascular mortality of culprit-only group and immediate CR group and staged CR group: There was no difference between three groups (*P* < 0.578). CR, complete revascularization.

Fig. 2
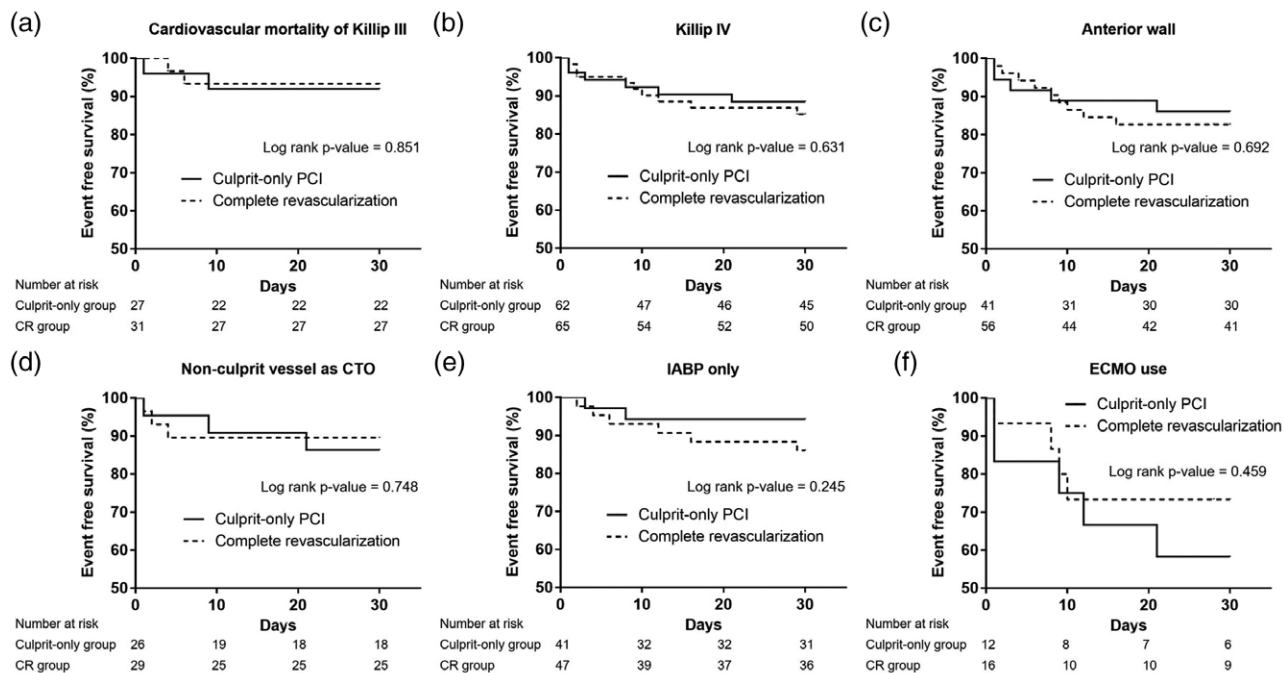
Kaplan–Meier curves of 30-day cardiovascular mortality in different subgroups. (a) Kaplan–Meier curve of 30-day cardiovascular mortality of STEMI patients with Killip III: There was no difference between culprit-only group and CR group ($P = 0.491$). (b) Kaplan–Meier curve of 30-day cardiovascular mortality of STEMI patients with Killip IV: There was no difference between culprit-only group and CR group ($P = 0.631$). (c) Kaplan–Meier curve of 30-day cardiovascular mortality of STEMI patients with anterior wall involvement: There was no difference between culprit-only group and CR group ($P = 0.692$). (d) Kaplan–Meier curve of 30-day cardiovascular mortality of STEMI patients with non-culprit vessel as chronic total occlusion lesion: There was no difference between culprit-only group and CR group ($P = 0.748$). (e) Kaplan–Meier curve of 30-day cardiovascular mortality of STEMI patients with intra-aortic balloon pumping support only: There was no difference between culprit-only group and CR group ($P = 0.245$). (f) Kaplan–Meier curve of 30-day cardiovascular mortality of STEMI patients with extra-corporeal membrane oxygenation support: There was no difference between culprit-only group and CR group ($P = 0.459$). CR, complete revascularization; STEMI, ST-segment elevation myocardial infarction.

instability, and reduced left ventricular (LV) performance and not only related to contrast volume [19]. Therefore, AKI may be related to critical status and may influence the clinical outcomes about complete revascularization for the critical patients with STEMI and MVD.

According to an observational study, complete revascularization was not independently associated with decreased short-term and long-term all-cause mortality, and only old age, Killip ≥ II, and left main artery disease were associated with increased mortality [20]. In another observational study about ECMO and STEMI patients, around 40% patients experienced mortality at a 30-day follow-up even though greater than half of the study patients underwent immediate or staged complete revascularization [21]. PCI for non-culprit vessel may cause more myocardial injury and a worse LV performance in this group of patients in a critical condition even with mechanical and vasoactive agent support. One meta-analysis also supports staged complete revascularization and notes it may improve short-term and long-term outcomes [22].

In our study, all STEMI patients were Killip ≥ III status and were diagnosed with MVD. Baseline characteristics were similar between the study groups, except higher BMI was noted in the staged complete revascularization group (compared to the immediate complete revascularization group). In daily practice, interventionists may consider performing complete revascularization in those patients with anterior wall STEMI because anterior wall involvement may portend a poor prognosis [4]. We compared the clinical outcomes between culprit-only PCI group and multi-vessel PCI group. Better 30-day and 1-year cardiovascular mortality and all-cause mortality were found in the staged complete revascularization group (when compared to immediate complete revascularization group). In addition, it appeared that the staged complete revascularization group had the best performance though it was small and underpowered. Therefore, additional large randomized trials are required to elucidate the optimal strategies for the non-culprit vessel in STEMI patients with MVD and in critical clinical condition.

Limitations
This was a retrospective cohort study involving patients from a single-center and the findings were hypothesis-generating. However, we shared the results of the

clinical outcomes about the effect of complete revascularization in critical STEMI patients with MVD, and with Killip ≥ III. We also included patients who needed mechanical support unlike prior research in the area. Our research provides insight into possible improvements in healthcare protocols for critical STEMI patients with MVD in the future.

Conclusions

Complete revascularization was associated with a trend toward a higher incidence of post-PCI AKI and seemed not to improve 30-day and 1-year clinical outcomes. Staged complete revascularization during the same hospitalization may have better clinical outcomes than immediate complete revascularization.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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