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Original Article

Percutaneous coronary intervention improved outcomes of cardiac arrest after acute myocardial infarction: a 2-year study

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Abstract: Aim: To assess the effects of percutaneous coronary intervention (PCI) on short- and long-term outcomes and complication incidence in resuscitated patients with cardiac arrest (CA) after acute myocardial infarction (AMI). Methods: In a retrospective study from January 2005 to April 2014, 2914 consecutive CA patients admitted to the Emergency Department were studied. All patients with CA after AMI with successful cardiopulmonary resuscitation (CPR) were assessed and followed-up for 2 years. Results: A total of 104 patients with CA after AMI were resuscitated. The PCI group (n=63) showed significantly improved short- and long-term outcomes compared to the non-PCI group (n=41). Complication rates were similar between both groups. The PCI group contained 32 and 31 cardiogenic shock (CS) and non-CS patients, respectively. Angiography demonstrated that percent stenosis, not stenosis location, was determinant. Short- and long-term outcomes were similar between the two subgroups. In addition, PCI patients were divided into acute ST-elevation myocardial infarction (STEMI) (n=50) and non-STEMI (NSTEMI) (n=13) subgroups. Short- and long-term outcomes between these two subgroups were also similar. ClinicalTrials.gov: NCT02576691. Conclusions: PCI improved short- and long-term outcomes in patients with CA after AMI without increasing the occurrence of complications. Furthermore, patients who have experienced CA after AMI are suggested to undergo PCI, regardless of CS occurrence and electrocardiogram (ECG) findings.

Keywords: Acute myocardial infarction, cardiac arrest, percutaneous coronary intervention, cardiogenic shock, short-term outcome, long-term outcome

Introduction

Survival rates after cardiac arrest (CA) reported in the recent literature are low, with an average of 6% of individuals surviving to hospital discharge and a 1-year survival rate of 4.79% (777/16206) in elderly out-of-hospital cardiac arrest (OHCA) patients, indicating no improvement in recent years [1, 2]. This high mortality is often due to the so-called "post-cardiac arrest syndrome", characterized by multi-organ ischemic reperfusion injury, largely involving the brain and myocardium.

Our previous study [3] about all-cause CA prognosis supported the low survival rates mentioned above, but our recent further research has found that CA after acute myocardial infarction (AMI) was associated with better outcomes. Some patients received coronary angiography (CAG)/percutaneous coronary intervention (PCI) as post-resuscitation care. Several reports have proposed that CAG/PCI can improve short-term outcome among resuscitated patients with CA after acute myocardial infarction (AMI) [4-6], but studies assessing long-term survival are scarce. Furthermore, a follow up period of 1 year is generally adopted [7, 8]. Cardiogenic shock (CS) in CA after AMI is considered to have a high risk for complications [9, 10], which are strongly related to the high fatality rate. Studies evaluating patients with CS in CA after AMI treated with PCI are very limited. In addition, research assessing the effect of PCI on CA after acute ST-elevation myocardial infarction (STEMI) is more abundant [11-14]. However, the evidence was not sufficient to

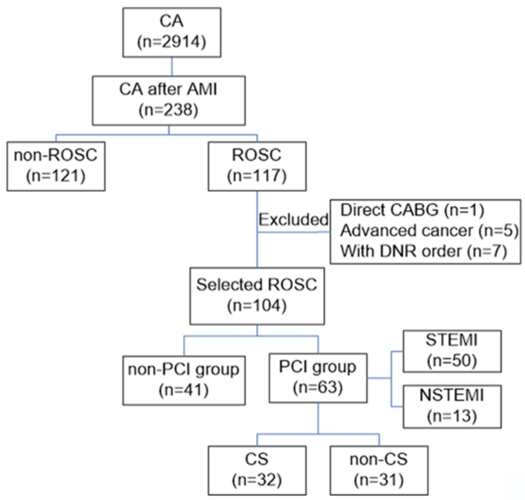

Figure 1. Flowchart describing the study population. A total of 2914 consecutive cardiac arrest (CA) patients from January 2005 to April 2014 were studied. Of these, 238 cases had CA after acute myocardial infarction (AMI). Additionally, 104 selected return of spontaneous circulation (ROSC) patients were divided into percutaneous coronary intervention (PCI) and non-PCI groups. The PCI group was divided into two pairs of subgroups: cardiogenic shock (CS) and non-CS subgroups and acute ST-elevation myocardial infarction (STEMI) and non-STEMI (NSTEMI) subgroups. CABG: coronary artery bypass grafting; DNR: do-not-resuscitate.

determine whether PCI improved the outcome in CA after non-STEMI (NSTEMI) [5, 15, 16]. Finally, it is still argued that bleeding complications are increased by CAG/PCI [17, 18].

Materials and methods

A total of 2914 consecutive CA patients, including 1988 males and 926 females, mean age 65.7 ± 11.5 years old, admitted to the Emergency Department were studied, and data collected in the general ward and all Intensive Care Units of the hospital from January 2005 to April 2014 were analyzed. Two-hundred and thirty-eight patients had CA after AMI. Diagnosis of AMI [19, 20] was confirmed by the typical increase in biochemical markers of myocardial necrosis, with at least one of the following: (a) ischemic symptoms; (b) development of pathologic Q waves on an electrocardiogram (ECG); (c) ECG changes indicative of ischemia (ST segment elevation or depression); (d) coronary artery intervention (e.g., coronary angioplasty). Of these patients, 117 cases had a return of spontaneous circulation (ROSC). However, 5 cases of late tumor, 1 patient who underwent coronary artery bypass grafting (CABG) after CAG, and 7 cases with do-not-resuscitate (DNR) orders were excluded. Finally, 104 ROSC patients with CA after AMI were enrolled and followed up for 2 years by telephone and/or interview. Two emergency physicians (one collected data while the other verified) with more than 2 years of work experience collected data according to Utstein recommendations [21]: demographic data, past history, recent history (including pre and post CA), ECG changes, PCI information, complications and outcome. The selected ROSC patients were divided into two groups: PCI (n=63) and non-PCI (n=41). Whether PCI was performed or not depended on the patient factors (CA location, the severity after cardiopulmonary resuscitation (CPR)), guardian factors (economy, the relationship to the patient), and doctor factors. The PCI group was further divided into two pairs of subgroups: CS (n=32) and non-CS (n=31); and STEMI (n=50) and NSTEMI (n=13) (**Figure 1**).

Procedural definitions

The PCI group was composed of patients who underwent PCI during ROSC or after CA. The non-PCI group included patients who did not undergo PCI or were subjected to PCI before CA. ROSC was considered following a clinical assessment, with vital signs comprising a palpable pulse >20 s or systolic blood pressure (SBP) >60 mmHg [21]. The CS subgroup included cases complicated by CS, defined according to the SHOCK (should we emergently revascularize occluded coronaries for cardiogenic shock) trial as a systolic blood pressure <90 mmHg and/or the need for vasopressor/inotropic agents to maintain a systolic blood pressure >90 mmHg, signs of organ hypoperfusion with cold extremities, and reduced urine output or an arterial lactate level >2 mmol/l [22, 23]. The STEMI subgroup included patients with electrocardiographic ST-segment elevation. ST-segment elevation was considered pathologic with an elevation of 1 mm in 2 contiguous limb leads and 2 mm in precordial leads. Serious arrhythmias were considered for ventricular tachycardia (VT), ventricular fibrillation (VF), and bradycardia <40/min or tachycardia >130/min [18]. Short-term outcomes encompassed 24 hours of survival, survival to discharge and survival to discharge with favorable neurological recovery rates. Long-term outcomes included 1-year and 2-year survival rates. The neurological status was assessed at

Table 1. Baseline characteristics

	PCI group (n=63)	Non-PCI group (n=41)	*p* value
General information			
Male	49 (77.8)	25 (61.0)	0.065
Age	64.4 ± 11.6	65.6 ± 9.2	0.557
Past history			
Hypertension	30 (47.6)	25 (61.0)	0.182
Diabetes	12 (19.0)	14 (34.1)	0.082
Personal history			
Long-term smoking	36 (57.1)	19 (46.3)	0.281
Information during CA			
IHCA	52 (82.5)	33 (80.5)	0.791
Response time ≤5 min	59 (93.7)	37 (90.2)	0.794
Ouration ≤15 min	44 (69.8)	26 (63.4)	0.495
CPR ≥2 times	16 (25.4)	7 (17.1)	0.318
LVEF ≥40%	40 (63.5)	22 (53.7)	0.318
Tracheal intubation	39 (61.9)	31 (75.6)	0.145
Vasopressors	30 (47.6)	23 (56.1)	0.398
STEMI	50 (79.4)	27 (65.9)	0.125
Complications			
Cardiogenic shock	32 (50.8)	24 (58.5)	0.439
Acute heart failure	23 (36.5)	10 (24.4)	0.194
Treatment			
IABP	12 (19.0)	8 (19.5)	0.953

Data are shown as n (%); PCI: percutaneous coronary intervention; CA: cardiac arrest; IHCA: in-hospital cardiac arrest; CPR: cardiopulmonary resuscitation; LVEF: left ventricular ejection fraction; STEMI: acute ST-elevation myocardial infarction; IABP: intra-aortic balloon pumping.

that time using the cerebral performance category. A score of 1 or 2 indicated a good neurological outcome [24].

Statistical methods

Data were analyzed using the statistical program SPSS Version 18.0 for Windows. Numerical data are presented as the means ± standard deviation, and categorical data were expressed as percentages. Student's t-test was used for numerical variables, and Pearson's chi-square test or Fisher's exact test were used for categorical variables. The chi-square test was used to evaluate the effect of PCI on complications and outcomes. Two-sided P<0.05 was considered statistically significant.

Results

A total of 104 ROSC patients after AMI, including 74 males and 30 females, were included in this study. Their mean age was 64.9 ± 10.7 years old. Baseline characteristics of the PCI (n=63) and non-PCI (n=41) groups are shown in **Table 1**. Compared with the non-PCI group, the PCI group showed no statistically significant differences in baseline characteristics.

In the PCI group, 59 patients had an infarct-related artery. Most of these cases (82.5%) were left anterior descending artery (LAD) or multiple vessels with significant stenosis. Three cases had multivessel disease without a culprit lesion. Six cases had significant stenosis (<75%). Compared with the non-CS subgroup, the CS subgroup showed no statistically significant differences in stenosis location. However, for the mean percentage stenosis size, the CS subgroup was more severe. Statistically significant differences were found in the right coronary artery (RCA) between the CS and non-CS subgroups (96.6% vs. 78.6, P=0.002) (**Table 2**).

The Kaplan-Meier survival curve shows that the survival percentage of the PCI group was significantly increased compared to the non-PCI group with respect to survival to 2 years in 104 patients receiving successful CPR after CA. In 56 CS patients, the survival percentage in the PCI group was also increased compared to the non-PCI group (**Figure 2**). The short- and long-term outcomes in the PCI and non-PCI groups are summarized in **Table 3**. Compared with the non-PCI group, the PCI group was significantly different in short- and long-term outcomes. Furthermore, the 2-year survival rate was markedly decreased in the non-PCI group compared to the survival to discharge rate (24.4% vs. 53.7%, P=0.002). In contrast, the 2-year survival and survival to discharge rates were similar in the PCI group (82.5% vs. 90.5%, P=0.192). Of the 32 cases in the CS subgroup, 9 (28.1%) were comatose during PCI. In the non-CS group, 9/31 (29.0%) cases were comatose at admission. The non-CS and CS subgroups had similar short- and long-term outcomes. Of the 50 patients in the STEMI subgroup, 28 (56.0%) had CS, and 4/13 (30.8%) in the NSTEMI subgroup had CS, indi-

Table 2. Location and size of stenosis in the CS and non-CS subgroups

	PCI group (n=63)	CS (n=32)	Non-CS (n=31)	*p* value
Number of vessels with significant stenosis				
0	4 (6.3)	2 (6.3)	2 (6.5)	1.000
Single	23 (36.5)	12 (37.5)	11 (35.5)	0.868
LAD	16 (25.4)	8 (25.0)	8 (25.8)	0.941
LCX	2 (3.2)	1 (3.1)	1 (3.2)	1.000
RCA	5 (7.9)	3 (9.4)	2 (6.5)	1.000
Multivessel disease with culprit lesion	33 (52.4)	16 (50.0)	17 (54.8)	0.701
Multivessel disease without culprit lesion	3 (4.8)	2 (6.3)	1 (3.2)	1.000
Size of vessels with percent stenosis				
LM	63.2 ± 21.2 (11)	68.1 ± 21.4 (8)	50.0 ± 17.3 (3)	0.225
LAD	85.4 ± 15.0 (48)	87.7 ± 14.2 (22)	83.5 ± 15.7 (26)	0.332
LCX	77.7 ± 17.2 (29)	79.5 ± 16.5 (12)	76.5 ± 18.0 (17)	0.648
RCA	87.6 ± 17.2 (30)	96.6 ± 10.4 (15)	78.6 ± 18.1 (15)	0.002

Data for the number of stenotic vessels are shown as n (%); Data for the size of percentage stenosis of the vessels are shown as the means ± standard deviation (n); CS: cardiogenic shock; PCI: percutaneous coronary intervention; LAD: left anterior descending artery; LCX: left circumflex artery; RCA: right coronary artery; LM: left main artery.

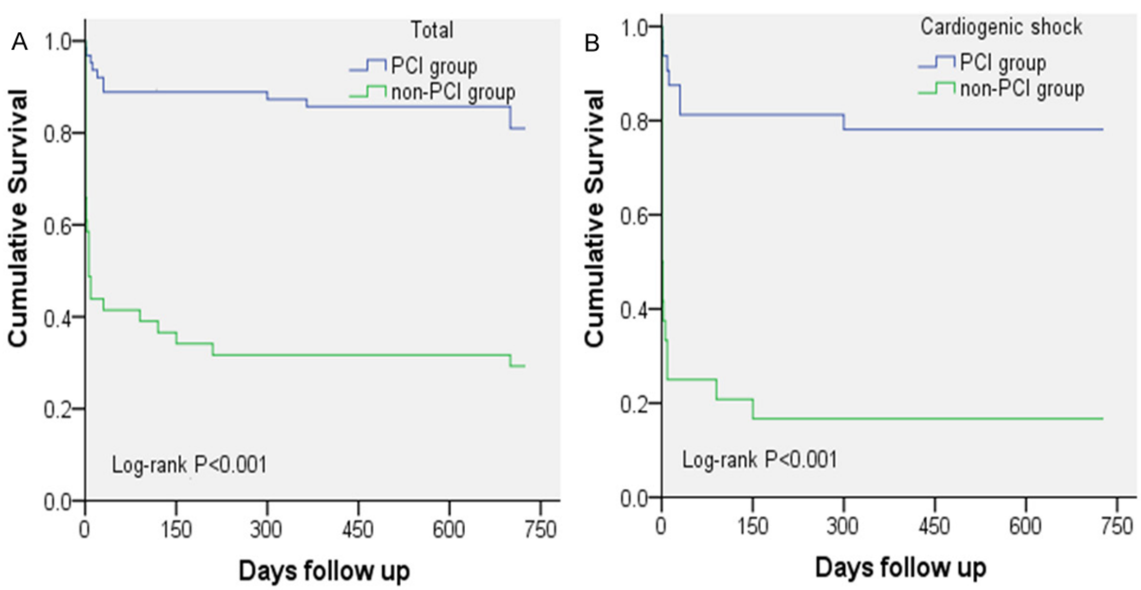

Figure 2. Kaplan-meier survival curve. A. The Kaplan-Meier survival curve of 104 patients shows survival to 2 years. B. Survival curve of 56 cardiogenic shock patients (percutaneous coronary intervention (PCI) group, n=32; non-PCI group, n=24) shows survival to 2 years. Both survival curves show that the survival percentage of the PCI group was significantly greater than that of the non-PCI group.

cating no statistically significant difference in CS between the patients in the two subgroups (P=0.105).

In the PCI and non-PCI groups, the occurrences of complications were 47 (74.6%) and 32 (78.0%), respectively, including pulmonary infection in 34 (54.0%) and 20 (48.8%) patients, serious arrhythmia in 25 (39.7%) and 13 (31.7%) individuals, and bleeding in 5 (7.9%) and 7 (17.1%) subjects, respectively. The 5 bleeding cases in the PCI group were in the digestive tract (n=4) or were subcutaneous (n=1). In the non-PCI group, the 7 cases of bleeding were in the digestive tract (n=3), intracranial (n=3), or subcutaneous (n=1). The PCI and non-PCI groups showed no statistically significant differences in complications (**Figure 3**).

Discussion

Resuscitated patients with CA after AMI are not rare in the clinic. After intervention treatment, the efficacy (short- and long-term outcome) and

Table 3. Short- and long-term outcomes in the PCI and non-PCI groups

Variable		N	24-hour survival		Survival to discharge		Survival to discharge with favorable neurological recovery		1-year survival		2-year survival		
			N (%)	*p* value	N(%)	*p* value	N (%)	*p* value	N (%)	*p* value	N (%)	*p* value	p^{*}value
Total	PCI group	63	63 (100)	<0.001	57 (90.5)	<0.001	51 (81.0)	<0.001	55 (87.3)	<0.001	52 (82.5)	<0.001	0.192
	non-PCI group	41	30 (73.2)		22 (53.7)		16 (39.0)		12 (29.3)		10 (24.4)		0.002
PCI group	STEMI Group	50	50 (100)	1.000	47 (94.0)	0.181	42 (84.0)	0.417	46 (92.0)	0.084	43 (86.0)	0.313	0.317
	NSTEMI Group	13	13 (100)		10 (76.9)		9 (69.2)		9 (69.2)		9 (69.2)		1.000
PCI group	CS Group	32	32 (100)	1.000	27 (84.4)	0.212	24 (75.0)	0.095	25 (78.1)	0.065	25 (78.1)	0.348	0.522
	Non-CS group	31	31 (100)		30 (96.8)		29 (93.5)		30 (96.8)		27 (87.1)		0.351

Data are shown as n (%); PCI: percutaneous coronary intervention; N: number; STEMI: acute ST-elevation myocardial infarction; NSTEMI: non-acute ST-elevation myocardial infarction; CS: cardiogenic shock. *p* value indicated comparison with the non-PCI group, and p^{*} value indicates comparison with survival to discharge.

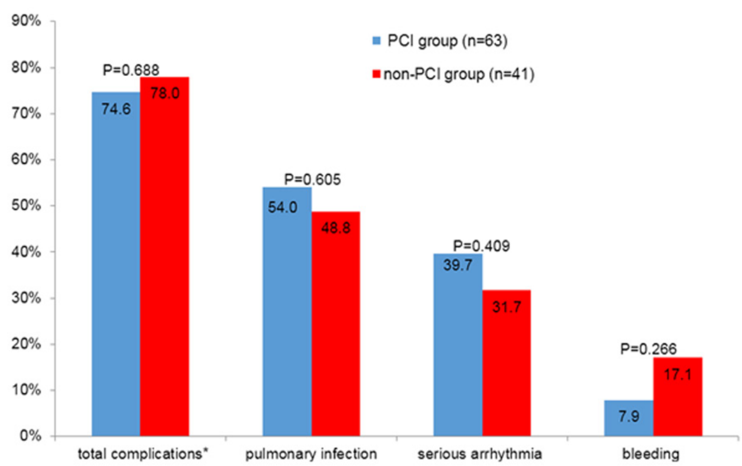

Figure 3. Complications (%) in the percutaneous coronary intervention (PCI) and non-PCI Groups. *: total complications include pulmonary infection, bleeding, serious arrhythmia, and cardiac rupture, but not acute heart failure or cardiogenic shock.

safety of PCI treatment in these cases are still debatable and constitute popular topics of research, especially in cases complicated by CS or ECG showing NSTEMI.

The effects of PCI in resuscitated patients with CA after AMI differ according to studies. Generally, CA patients after AMI who are administered PCI show an excellent prognosis. All-cause CA prognoses in our previous study [3] from January 2005 to December 2011 in the emergency department were as follows: 187 (25.8%) had ROSC, 100 (13.8%) survived for 24 hours, 48 (6.6%) survived to discharge, and 23 (3.2%) survived to discharge with favorable neurological outcomes. Representative studies about CA after AMI are listed in **Table 4**. Here, good short- and long-term outcomes were obtained because our hospital performs more than 1000 primary PCI yearly, with a detailed protocol used for chest pain. The mean duration between CA and balloon time for PCI was 1 hour in early cardiac catheterization patients. In the non-PCI group, the 2-year survival rate was markedly reduced compared to the survival to discharge rate, while a similar change was not observed in the PCI group. This outcome corroborated findings by Pedersen et al. [25] and Doost Hosseiny et al. [26] that showed that patients treated with PCI who had passed a period of stability have an excellent prognosis, with an extremely low annual risk of successive cardiac death.

CS induced by AMI may result from extensive left ventricular infarction or mechanical complications [20], which are considered high risk complications and are strongly related to the fatality rate [9, 10, 23]. In our study, CAG showed that CS was more common for LAD or multivessel lesions. These results were in agreement with Mylotte et al. [27] who reported 66/266 LAD and 169/266 multivessel lesions. Interestingly, LAD lesions were shown to have less hemodynamic stability [28]. Similarly, analysis by CAG showed that CA cases mainly occur due to the proximal occlusion of the LAD or multivessel lesions for wide involvement of the myocardium. Our study also found that 1. the differences between the CS and non-CS subgroups lie in percent stenosis, not stenosis location; 2. both the CS and non-CS subgroups benefit from CAG/PCI; and 3. non-CS was better than CS, but there was no statis-

Table 4. Short- and long-term outcomes of PCI for resuscitated patients with CA after AMI

Author	Type	Cases	Survival to discharge rate (%)	Survival to discharge with favorable neurologicalrecovery rate (%)	1-year survival rate (%)	2-year survival rate (%)
Velders et al [4]	CA after STEMI	218	84.0	77.0	-	-
Karl & Rahman [5]	CA after AMI	930	60.0	87.0	-	-
Karl & Rahman [5]	CA after STEMI	419	60.8	84.7	-	-
Neumar et al [6]	CA after STEMI	40	75.0	90.0	-	-
Siudak et al [7]	CA after STEMI	42	92.9	-	80.9	-
Lim et al [8]	CA after AMI	88	62.5	-	60.2	-
Our study	CA after AMI	63	90.5	81.0	87.3	82.5

PCI: percutaneous coronary intervention; CA: cardiac arrest; AMI: acute myocardial infarction; STEMI: acute ST-elevation myocardial infarction.

tical significance between them, which indicated that CA patients with CS need PCI immediately. This may explain why, after the opening of infarction-related blood vessels, CA after AMI complicated with CS is alleviated. Therefore, in the case of CA after AMI, PCI should be performed as soon as possible, without waiting for hemodynamic stability. Studies have shown that emergency interventional therapy can be used as an important measure in patients with hemodynamic instability. Even with a comatose patient, it should not be considered taboo to immediately perform CAG/PCI [6].

The requirements of STEMI or NSTEMI leading to CA for PCI are not entirely the same. Based on a randomized clinical study performed in 2003, emergency PCI was recommended as the standard STEMI treatment in Denmark [11]. Moreover, observational studies also have emphasized the importance of STEMI treatment with emergency PCI [12-14]. However, some scholars have described CA cases caused by unstable plaque or coronary artery embolism, of whom approximately 30-58% present NSTEMI [5, 15, 16]. Therefore, patients with CA caused by cardiac factors are suggested to undergo emergency PCI. Sunde et al. [29] performed CAG for 47/61 (77%) patients with out-of-hospital cardiac arrest caused by cardiac factors and found 36/47 (76%) of cases of AMI, with 30/36 (83%) with extreme main coronary artery occlusion. In our study, both STEMI and NSTEMI leading to CA benefit from CAG/PCI. STEMI was better than NSTEMI, but there was no statistical significance between them. The 2015 American Heart Association guidelines recommend [30] the following: Coronary angiography should be performed emergently for OHCA patients with suspected cardiac etiology of arrest and ST elevation on ECG (Class I). Emergency coronary angiography is reasonable for select (e.g., electrically or hemodynamically unstable) adult patients who are comatose after OHCA of suspected cardiac origin but without ST elevation on ECG (Class IIa). Therefore, whether STEMI or not, resuscitated patients with CA after AMI can benefit from CAG/PCI.

Some scholars have argued that PCI was associated with better outcomes in resuscitated patients with CA after AMI, but it can result in increased incidence of bleeding complications [17, 18]. Nielsen et al. reported bleeding requiring transfusion in 4% of CA induced-by AMI cases, with a significantly higher risk if CAG/PCI is performed (2.8% vs. 6.2%, P=0.02) [18]. Nielsen et al. [31] assessed 765 patients after CPR and revealed pulmonary infection, hemorrhage, and VT/VF rates of 48%, 6%, and 7%-14%, respectively, suggesting that CAG/PCI increased the frequency of bleeding and sepsis. In our study, as shown above, compared with the non-PCI group, the PCI group did not show statistically significant differences in complications, especially serious bleeding of key regions, such as within the skull. Therefore, we believe that PCI does not increase the incidence of complications, in agreement with findings by Batista et al. [32].

Conclusion

Patients with CA after AMI and treated with PCI who pass a period of stability have an excellent prognosis. Indeed, PCI improved short- and long-term outcomes in resuscitated patients with CA after AMI without increasing the occurrence of complications. Furthermore, CA after AMI patients are suggested to undergo PCI regardless of cardiogenic shock occurrence and electrocardiography findings. A prospective study enrolling a larger number of CA after AMI patients will be needed to exclude confounding factors.

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Disclosure of conflict of interest

None.

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