Relation of Chronic Total Occlusion to In-Hospital Mortality in the Patients With Sudden Cardiac Arrest Due to Acute Coronary Syndrome

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Although the presence of chronic total occlusion (CTO) has been associated with long-term mortality in the patients with ST-segment elevation myocardial infarction, the influence of having CTO on in-hospital mortality in sudden cardiac arrest (SCA)-acute coronary syndrome (ACS) patients has not been reported. Therefore, we examined the association between the presence of CTO and in-hospital mortality in those patients. Consecutive 106 SCA-ACS patients who received coronary angiography were retrospectively included. The factors associated with in-hospital mortality were analyzed. Among 106 patients, 40 (38%) patients died during hospitalization. Multivariate analysis revealed presence of CTO dependent on infarct-related artery (IRA-dependent-CTO) (hazard ratio [HR] = 2.88, p = 0.004), diabetes mellitus (HR = 2.04, p = 0.044), percutaneous cardiopulmonary support use (HR = 2.22, p = 0.045), successful recanalization (HR = 0.31, p = 0.004), and peak creatine kinase muscle-brain fraction (HR = 1.11, p < 0.001) were significantly associated with mortality. In conclusion, presence of IRA-dependent-CTO was significantly associated with in-hospital mortality in SCA-ACS patients. **(Am J Cardiol 2019;123:1915−1920)**

Although some reported that percutaneous coronary interventions (PCI) of chronic total occlusion (CTO) are beneficial regardless of myocardial ischemia, the indication of PCI for CTO is still controversial.[1−4] Having nonculprit CTO would increase the area at risk and infarct size in the patients with acute coronary syndrome (ACS). Although ACS patients with sudden cardiac arrest (SCA) are known to have poor outcome[5] and the presence of CTO has been associated with long-term mortality in the patients with ST-segment elevation myocardial infarction,[6] the influence of having CTO on in-hospital mortality in SCA-ACS patients has not been reported.

Methods

From January 2009 to December 2016, 112 SCA patients suspected of ACS were treated in the Cardiovascular Division, National Hospital Organization Osaka National Hospital (Osaka, Japan). In 106 in those 112 patients, ACS was confirmed as the cause of SCA by emergency coronary angiography. We retrospectively included those 106 patients and analyzed the factors associated with in-hospital mortality.

The culprit of ACS was treated by PCI except for 4 patients who underwent coronary artery bypass grafting. Nonculprit severe stenosis was occasionally treated by PCI by the discretion of interventionists; however, the recanalization of CTO was not attempted at any time during hospitalization in any patient. The totally occluded lesions that were not suspected as the culprit of ACS were defined as CTO in the present study.

The distal vessel area from CTO is often perfused by the collateral channels from another coronary vessel. If the donor vessel of the collateral channels is occluded by ACS, the myocardium perfused by infarct-related artery (IRA) and that perfused by collateral channels will have ischemia or infarction simultaneously. This kind of CTO is defined as "IRA-dependent-CTO."

The patients' data on admission were compared between those who died during hospitalization and those who survived, and multivariate analysis was also performed to clarify the factors associated with in-hospital mortality especially focusing on the presence of CTO or IRA-dependent-CTO.

Catheterization was performed via the femoral, brachial, or radial artery approach using a 6-Fr or 7-Fr sheath and catheters. Intravenous heparin (8,000 U) was initially administered and additional dose was administered to keep activated coagulation time >300 minutes. Coronary angiogram was recorded by Artis zee biplane (Siemens Healthcare Japan, Tokyo, Japan). Intravascular ultrasound was always used as a guide of PCI. If the patients were not taking aspirin 100 mg/day and clopidogrel 75 mg/day or

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prasugrel 3.75 mg/day (dual antiplatelet therapy), the loading doses of those antiplatelet drugs (aspirin 100 mg/day and clopidogrel 300 mg/day or prasugrel 20 mg/day) were administered before PCI, which were the standard recommended doses in Japan. Anti-GP IIb/IIIa inhibitors were not used in any patient as they were not approved in Japan. Final TIMI-3 flow after PCI or coronary artery bypass grafting was regarded as successful recanalization.

The study patients included 100 out-of-hospital SCA patients and 6 in-hospital SCA patients. All out-of-hospital SCA patients were transferred to Osaka National Hospital by emergency life-saving technicians. Emergency life-saving technicians and medical staffs performed cardiopulmonary resuscitation according to the recommendations of the Japan Resuscitation Council Guidelines 2010, which were based on the American Heart Association and the International Liaison Committee on Resuscitation guidelines. Patients' data were retrospectively collected from the clinical records. Onset-to-door time of in-hospital SCA patients was regarded as 0 minute.

Hypertension was defined as blood pressure >140/90 mm Hg or the use of antihypertensive drugs. Diabetes mellitus was defined as HbA1c (National Glycohemoglobin Standardization Program) ≥6.5% or the use of oral drugs for diabetes mellitus or insulin therapy. ACS included acute myocardial infarction with/without ST elevation defined by the Joint European Society of Cardiology/American College of Cardiology Committee, and unstable angina defined according to the Braunwald classification.

This study was approved by the Osaka National Hospital Institutional Review Board #2 (Approval No. 18028). Since this was a retrospective study, informed consent from each patient was not required.

Categorical variables were expressed as frequency and were compared between groups by chi-square or Fisher's exact test. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, and were compared between groups by unpaired Student's *t* test or Mann-Whitney *U* test according to their distributions. Cox proportional hazards regression analysis was performed to clarify the factors associated with in-hospital mortality, including diabetes mellitus, number of diseased vessels, presence of CTO or IRA-dependent-CTO, ventricular fibrillation, intra-aortic balloon pump use, percutaneous cardiopulmonary support (PCPS) use, successful recanalization, and peak creatine kinase muscle-brain fraction (CK-MB) as independent variables. All statistical analyses were regarded as significant when p value was <0.05. Statistical analysis was performed by MedCalc version 16.4.3 (MedCalc Software, Ostend, Belgium).

Results

The patients' characteristics comparing the patients who survived and those who died during hospitalization were presented in Table 1. Among 40 patients who died, the causes of death were cardiogenic shock/arrhythmia in 29, infection in 5, brain damage in 2, bleeding in 3, and renal failure in 1 patient. In 21 patients with CTO, coronary artery disease had been known only in 57% of patients. Those who had been known to have coronary artery disease had relatively higher frequency of aspirin (67% vs 11%, p = 0.02) and statin use (58% vs 11%, p = 0.07) and lower level of low-density lipoprotein cholesterol (mean [interquartile range], 89 [59 to 107] mg/dl vs 128 [113 to 143] mg/dl, p = 0.04) than those who had not.

Patients were divided into 2 groups according to whether they had CTO (CTO group vs no-CTO group) or whether they had IRA-dependent-CTO (IRA-dependent-CTO group vs no-IRA-dependent-CTO group). Kaplan-Meier analysis revealed that in-hospital mortality was significantly higher in CTO group than in no-CTO group (62% vs 32%, log-rank p = 0.02; Figure 1) and in IRA-dependent-CTO group than in no-IRA-dependent-CTO group (91% vs 32%, log-rank p < 0.001; Figure 1).

Although Cox proportional hazards regression analysis revealed that presence of CTO was not significantly associated with in-hospital mortality (Table 2), presence of IRA-dependent-CTO, diabetes mellitus, PCPS use, successful recanalization, and peak CK-MB were significantly and independently associated with in-hospital mortality (Table 3).

Discussion

We have demonstrated for the first time that the presence of IRA-dependent-CTO was associated with increased in-hospital mortality in SCA-ACS patients.

Previous studies reported that bystander CPR, short time interval from call to hospital arrival, ventricular fibrillation at the scene, and rapid defibrillation by Automated External Defibrillator (AED) were associated with better clinical outcome of SCA patients.[7–10] In contrast, several studies reported that presence of nonculprit CTO was an independent risk of early and late mortality in the patients with ST-segment elevation myocardial infarction.[6,11,12] However, the influence of having CTO on in-hospital mortality in SCA-ACS patients has not been reported. In the present study, multivariate analysis revealed that the presence of IRA-dependent-CTO, need for intra-aortic balloon pump or PCPS, and large peak CK-MB were independent predictors of in-hospital death in SCA-ACS patients, which suggested that, in addition to the large infarct size and severe heart failure, the presence of IRA-dependent-CTO significantly and independently increased the in-hospital mortality.

Having ACS culprit in the collateral donor vessel to CTO would cause larger infarct size than in the cases without CTO, which would be a major probable mechanism for the increased mortality in the patients with IRA-dependent-CTO. Indeed, Lexis et al reported that peak CK-MB and long-term mortality were significantly higher in the patients with ST-segment elevation myocardial infarction patients with CTO than in those without.[13] We also demonstrated in the present study that peak CK-MB was significantly associated with in-hospital mortality; however, the presence of IRA-dependent-CTO was also significantly and independently associated with in-hospital mortality, suggesting that some other different mechanism should be involved. In the present study, pulseless electrical activity (PEA) as the initial rhythm was more frequent in CTO group than in no-CTO group (33% vs 8.2%, p = 0.006). Although the precise mechanism of this finding is unknown, PEA would be

Table 1
Patients characteristics (survived vs dead during hospitalization)

Variables	Survived (n = 66)	Dead (n = 40)	p Value
Age (years)	60 ± 12	64 ± 13	0.10
Men	55 (83%)	38 (95%)	0.08
Body mass index	24 (21-27)	24 (23-28)	0.28
Hypertension	34 (52%)	22 (55%)	0.73
Diabetes Mellitus	20 (30%)	21 (53%)	0.02
Current smoking	33 (50%)	17 (46%)	0.70
Prior heart failure admission	3 (4.5%)	4 (10%)	0.28
Prior myocardial infarction	8 (12%)	6 (15%)	0.77
Hemodialysis	1 (1.5%)	4 (10%)	0.07
Medications:			
Aspirin	8 (12%)	9 (23%)	0.18
P_2Y_{12} inhibitor	2 (3.0%)	6 (15%)	0.05
β-blocker	4 (6.1%)	4 (10%)	0.47
Angiotensin converting enzyme inhibitor/Angiotensin receptor blocker	12 (18%)	15 (38%)	0.03
Calcium blocker	10 (15%)	10 (25%)	0.31
Aldosterone antagonist	3 (4.5%)	2 (5.0%)	1.00
Statin	7 (11%)	10 (25%)	0.06
Diagnosis:			0.20
ST-elevation myocardial infarction	49 (74%)	25 (63%)	
Non-ST-elevation myocardial infarction	17 (26%)	15 (37%)	
Number of narrowed coronary arteries:			0.01
1	42 (64%)	17 (43%)	
2	16 (24%)	10 (25%)	
3	8 (12%)	13 (32%)	
Number of chronic total occlusion arteries:			0.01
0	58 (88%)	27 (68%)	
1	6 (9%)	8 (20%)	
2	2 (3%)	5 (12%)	
Coronary artery totally occluded:			0.85
Left anterior descending coronary artery	5 (50%)	8 (44%)	
Left circumflex coronary artery	1 (10%)	5 (28%)	
Right coronary artery	4 (40%)	5 (28%)	
Infarct-related artery-dependent-chronic total occlusion	1 (2%)	10 (25%)	<0.001
Hospitalization (days)	39 (28-57)	4 (3-10)	<0.001
In-hospital sudden cardiac arrest	3 (4.5%)	3 (7.5%)	0.67
Bystander cardio-pulmonary resuscitation	38 (58%)	25 (63%)	0.62
automated external defibrillator use	51 (77%)	24 (60%)	0.06
Initial rhythm:			0.02
Ventricular fibrillation	59 (89%)	28 (70%)	
Pulseless electrical activity	5 (7.6%)	9 (23%)	
Asystole	2 (3.0%)	3 (7.5%)	
Return of spontaneous circulation	66 (100%)	37 (93%)	0.02
Time to return of spontaneous circulation (min)	20 (10-32)	40 (26-50)	<0.001
Killip classification:			0.004
1	5 (8%)	1 (2%)	
2	20 (30%)	4 (10%)	
3	10 (15%)	2 (5%)	
4	31 (47%)	33 (83%)	
Culprit lesion of acute coronary syndrome:			0.57
Left anterior descending coronary artery	33 (50%)	21 (53%)	
Left circumflex coronary artery	9 (14%)	3 (7.5%)	
Right coronary artery	20 (30%)	9 (23%)	
Left main coronary artery	4 (6.2%)	7 (18%)	
Intra-aortic balloon pumping use	31 (47%)	35 (88%)	<0.001
Percutaneous cardiopulmonary support use	22 (33%)	29 (73%)	<0.001
Percutaneous coronary intervention	60 (91%)	34 (85%)	0.35
Coronary artery bypass grafting	3 (5%)	1 (3%)	1.00
Successful recanalization,	63 (96%)	31 (78%)	0.005
Onset-to-door time (min)	28 (24-34)	30 (22-39)	0.86
Door-to-balloon time (min)	117 (81-144)	129 (101-159)	0.07
Onset-to-balloon time (min)	152 (112-189)	160 (131-196)	0.14
Peak creatine kinase (mg/dl)	3274 (1106-5148)	7486 (2640-15568)	<0.001
Peak creatine kinase muscle-brain fraction (mg/dl)	290 (96-533)	698 (278-1353)	<0.001

Categorical variables are expressed as number (%). Continuous variables were expressed as mean ± standard deviation or median (IQR).

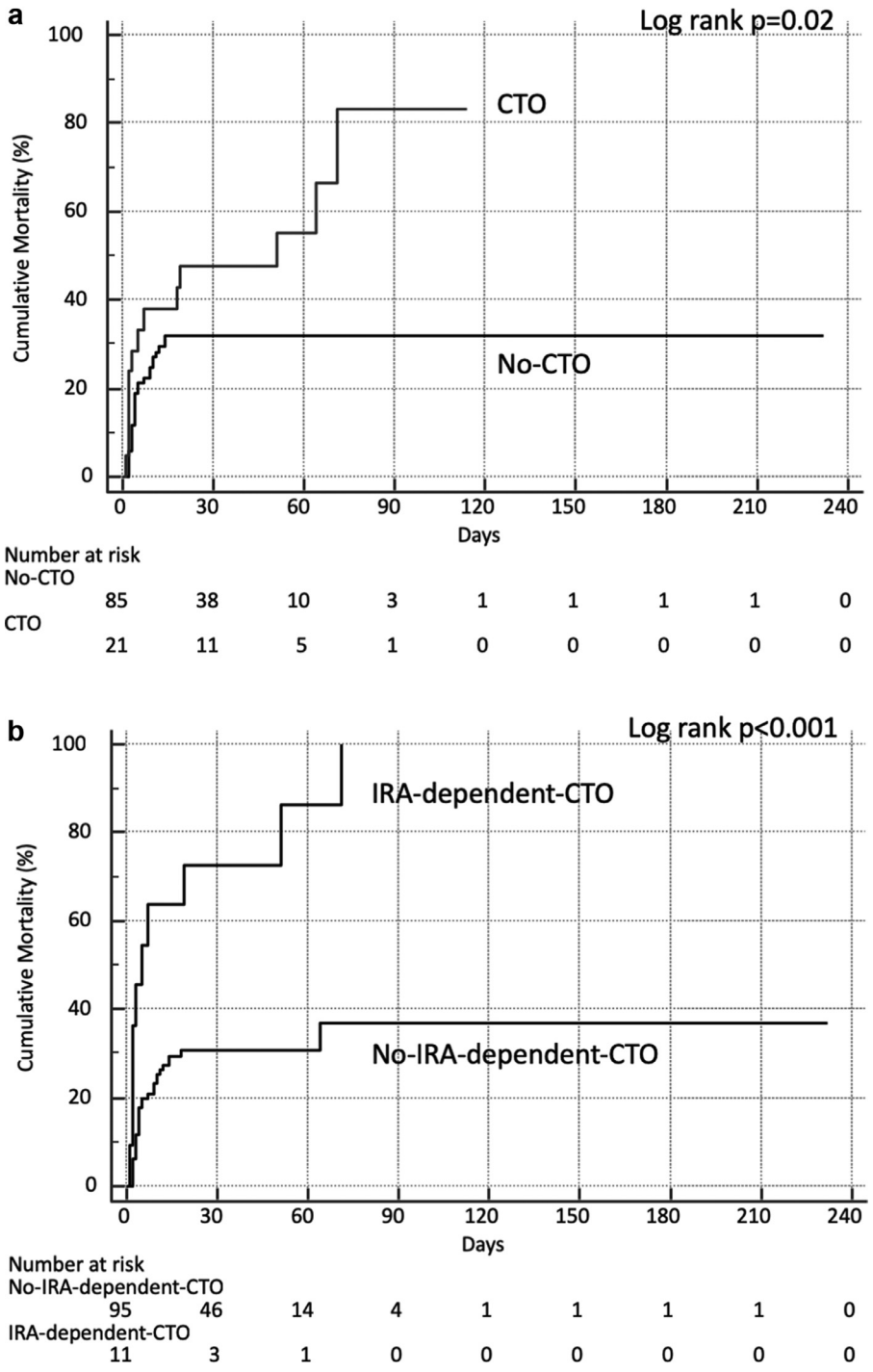

Figure 1. In-hospital mortality according to the presence or absence of CTO/ IRA-dependent-CTO lesions. Kaplan-Meier analysis showed that the presence of CTO lesions (A: log-rank p = 0.02) or IRA-dependent-CTO lesions (B: log-rank p < 0.001) were significantly associated with in-hospital mortality. CTO = chronic total occlusion. IRA = infarct-related artery.

caused by a large myocardial ischemia.[14] Therefore, ACS patients having IRA-dependent-CTO would easily develop PEA due to a large myocardial ischemia in the area perfused by ACS culprit vessel and CTO vessels. Previous studies reported that bystander-CPR did not improve survival rate of PEA patients[15,16]; therefore, it would be difficult to improve the outcome of those patients by conventional resuscitation approach. However, without IRA-dependent-CTO, PEA might be prevented and their outcome might be improved.

To prevent in-hospital death caused by SCA due to ACS, we should think about detecting coronary artery disease including CTO beforehand and managing their coronary artery disease and risk factors appropriately. Since we

Table 2
Cox proportional hazards regression analysis to evaluate the factors associated with in-hospital mortality including the presence of chronic total occlusion

Variables	Hazard ratio (95%CI)	p Value	Hazard ratio (95%CI)	p Value
Diabetes mellitus	1.93 (1.04-3.60)	0.04	1.97 (0.98-3.97)	0.057
Number of diseased vessels	1.49 (1.03-2.15)	0.03		
Presence of chronic total occlusion	2.13 (1.09-4.13)	0.03		
Ventricular fibrillation	0.44 (0.22-0.87)	0.02		
Intra-aortic balloon pumping use	5.17 (2.02-13.2)	0.001	3.17 (1.18-8.53)	0.022
Percutaneous cardiopulmonary support use	3.48 (1.73-6.99)	0.001		
Successful recanalization	0.47 (0.23-0.96)	0.04	0.33 (0.15-0.76)	0.009
Peak creatine kinase muscle-brain fraction ($\times 10^{-2}$ mg/dl)	1.09 (1.04-1.14)	<0.001	1.10 (1.04-1.17)	<0.001

Cox proportional hazards regression analysis was performed to clarify the factors associated with in-hospital mortality including diabetes mellitus, number of diseased vessels, presence of chronic total occlusion, ventricular fibrillation, intra-aortic balloon pumping use, percutaneous cardiopulmonary support use, successful recanalization, and peak creatine kinase muscle-brain fraction as independent variables.

Table 3
Cox proportional hazards regression analysis to evaluate the factors associated with in-hospital mortality including the presence of infarct-related artery-dependent-chronic total occlusion

Variables	Hazard ratio (95%CI)	p Value	Hazard ratio (95%CI)	p Value
Diabetes mellitus	1.93 (1.04-3.60)	0.04	2.04 (1.02-4.08)	0.044
Number of diseased vessels	1.49 (1.03-2.15)	0.03		
Infarct-related artery-dependent-chronic total occlusion	4.20 (2.04-8.63)	<0.001	2.88 (1.40-5.95)	0.004
Ventricular fibrillation	0.44 (0.22-0.87)	0.02		
Intra-aortic balloon pumping use	5.17 (2.02-13.2)	0.001		
Percutaneous cardiopulmonary support use	3.48 (1.73-6.99)	0.001	2.22 (1.02-4.84)	0.045
Successful recanalization	0.47 (0.23-0.96)	0.04	0.31 (0.14-0.67)	0.004
Peak creatine kinase muscle-brain fraction ($\times 10^{-2}$ mg/dl)	1.09 (1.04-1.14)	<0.001	1.11 (1.04-1.17)	<0.001

Cox proportional hazards regression analysis was performed to clarify the factors associated with in-hospital mortality including diabetes mellitus, number of diseased vessels, presence of infarct-related artery-dependent-chronic total occlusion, ventricular fibrillation, intra-aortic balloon pumping use, percutaneous cardiopulmonary support use, successful recanalization, and peak creatine kinase muscle-brain fraction as independent variables.

cannot eliminate the residual risk of ACS by aggressive risk reduction therapy, recanalization of CTO beforehand may be an option to reduce their mortality that should be tested by clinical trials.

This study was a retrospective, single-center small study; therefore, a further large-scale multicenter study would be needed to confirm the findings. Left ventricular ejection fraction (LVEF) or echocardiographic data were not available in the present study. Claessen et al demonstrated that the presence of CTO lesions was associated with reduced LVEF in PCI patients.[17] However, we could not evaluate LVEF in the present study, because some patients did not achieve return of spontaneous circulation. The data on the inotropic and antiarrhythmic agents were not available in the present study.

In conclusion, the presence of IRA-dependent-CTO was significantly associated with the higher in-hospital mortality in SCA-ACS patients.

Disclosures

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1. Hachamovitch R, Hayes SW, Friedman JD, Cohen I, Berman DS. Comparison of the short-term survival benefit associated with revascularization compared with medical therapy in patients with no prior coronary artery disease undergoing stress myocardial perfusion single photon emission computed tomography. *Circulation* 2003;107:2900–2907.
2. Safley DM, Koshy S, Grantham JA, Bybee KA, House JA, Kennedy KF, Rutherford BD. Changes in myocardial ischemic burden following percutaneous coronary intervention of chronic total occlusions. *Catheter Cardiovasc Interv* 2011;78:337–343.
3. Pancholy SB, Boruah P, Ahmed I, Kwan T, Patel TM, Saito S. Meta-analysis of effect on mortality of percutaneous recanalization of coronary chronic total occlusions using a stent-based strategy. *Am J Cardiol* 2013;111:521–525.
4. Hochman JS, Lamas GA, Buller CE, Dzavik V, Reynolds HR, Abramsky SJ, Forman S, Ruzyllo W, Maggioni AP, White H, Sadowski Z, Carvalho AC, Rankin JM, Renkin JP, Steg PG, Mascette AM, Sopko G, Pfisterer ME, Leor J, Fridrich V, Mark DB, Knatterud GL. Occluded Artery Trial Investigators. Coronary intervention for persistent occlusion after myocardial infarction. *N Engl J Med* 2006;355:2395–2407.
5. Żeliaś A, Stępińska J, Andres J, Trąbka-Zawicki A, Sadowski J, Żmudka K. Ten-year experience of an invasive cardiology centre with out-of-hospital cardiac arrest patients admitted for urgent coronary angiography. *Kardiol Pol* 2014;72:687–699.

6. Claessen BE, Dangas GD, Weisz G, Witzenbichler B, Guagliumi G, Möckel M, Brener SJ, Xu K, Henriques JP, Mehran R, Stone GW. Prognostic impact of a chronic total occlusion in a non-infarct-related artery in patients with ST-segment elevation myocardial infarction: 3-year results from the HORIZONS-AMI trial. *Eur Heart J* 2012;33:768–775.
7. Copley DP, Mantle JA, Rogers WJ, Russell RO Jr, Rackley CE. Improved outcome for prehospital cardiopulmonary collapse with resuscitation by bystanders. *Circulation* 1977;56:901–905.
8. White RD, Hankins DG, Bugliosi TF. Seven years' experience with early defibrillation by police and paramedics in an emergency medical services system. *Resuscitation* 1998;39:145–151.
9. Komatsu T, Kinoshita K, Sakurai A, Moriya T, Yamaguchi J, Sugita A, Kogawa R, Tanjoh K. Shorter time until return of spontaneous circulation is the only independent factor for a good neurological outcome in patients with postcardiac arrest syndrome. *Emerg Med J* 2014;31:549–555.
10. Eisenberg MS, Copass MK, Hallstrom AP, Blake B, Bergner L, Short FA, Cobb LA. Treatment of out-of-hospital cardiac arrests with rapid defibrillation by emergency medical technicians. *N Engl J Med* 1980;302:1379–1383.
11. Watanabe H, Morimoto T, Shiomi H, Furukawa Y, Nakagawa Y, Ando K, Kadota K, Kimura T. Chronic total occlusion in a non-infarct-related artery is closely associated with increased five-year mortality in patients with ST-segment elevation acute myocardial infarction undergoing primary percutaneous coronary intervention (from the CREDO-Kyoto AMI registry). *EuroIntervention* 2017;12:e1874–e1882.
12. Sanguineti F, Garot P, O'Connor S, Watanabe Y, Spaziano M, Lefèvre T, Hovasse T, Benamer H, Unterseeh T, Chevalier B, Morice MC, Louvard Y. Chronic total coronary occlusion treated by percutaneous coronary intervention: long-term outcome in patients with and without diabetes. *EuroIntervention* 2017;12:e1889–e1897.
13. Lexis CP, van der Horst IC, Rahel BM, Lexis MA, Kampinga MA, Gu YL, de Smet BJ, Zijlstra F. Impact of chronic total occlusions on markers of reperfusion, infarct size, and long-term mortality: a substudy from the TAPAS-trial. *Catheter Cardiovasc Interv* 2011;77:484–491.
14. Charlap S, Kahlam S, Lichstein E, Frishman W. Electromechanical dissociation: diagnosis, pathophysiology, and management. *Am Heart J* 1989;118:355–360.
15. Hallstrom A, Rea TD, Mosesso VN Jr, Cobb LA, Anton AR, Van Ottingham L, Sayre MR, Christenson J. The relationship between shocks and survival in out-of-hospital cardiac arrest patients initially found in PEA or asystole. *Resuscitation* 2007;74:418–426.
16. Väyrynen T, Kuisma M, Määttä T, Boyd J. Who survives from out-of-hospital pulseless electrical activity? *Resuscitation* 2008;76:207–213.
17. Claessen BE, van der Schaaf RJ, Verouden NJ, Stegenga NK, Engstrom AE, Sjauw KD, Kikkert WJ, Vis MM, Baan J Jr, Koch KT, de Winter RJ, Tijssen JG, Piek JJ, Henriques JP. Evaluation of the effect of a concurrent chronic total occlusion on long-term mortality and left ventricular function in patients after primary percutaneous coronary intervention. *JACC Cardiovasc Interv* 2009;2:1128–1134.