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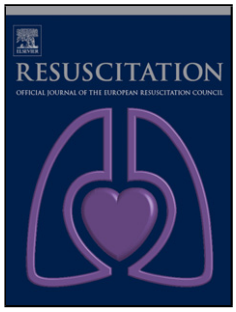

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PII: S0300-9572(20)30137-4

DOI: https://doi.org/doi:10.1016/j.resuscitation.2020.03.023

Reference: RESUS 8476

To appear in: *Resuscitation*

Received Date: 23 March 2020

Accepted Date: 25 March 2020

Please cite this article as: Song W, Liu Y, Ouyang Y, Chen W, Li M, Xianyu S, Yi S, Recommendations on cardiopulmonary resuscitation strategy and procedure for novel coronavirus pneumonia, *Resuscitation* (2020), doi: https://doi.org/10.1016/j.resuscitation.2020.03.023

Recommendations on cardiopulmonary resuscitation strategy and procedure for novel coronavirus pneumonia

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Word count: 1665

Since the outbreak of the epidemic situation of novel coronavirus pneumonia in Wuhan, China, in December 2019 (2019 coronavirus disease, COVID-19), the epidemic has spread to major cities in China and more than 20 foreign countries and regions in recent two months. By 15:00 on February 20, 2020, 75,647 patients had been diagnosed with COVID-19 globally, including 74,576 patients in China (including Taiwan, Hong Kong, and Macau), and 2,118 patients were dead [1]. A considerable portion of patients who died had relatively stable condition or cardiac arrest after sudden exacerbation of the condition; thus, it is urgent to further strengthen the prevention, control, and clinical rescue measures of the epidemic situation, in particular the management of patients with critical illness and cardiac arrest. To reduce the mortality and infection rate in the medical staff, three policies of prediction, prevention, and early warning of novel coronavirus pneumonia as well as cardiopulmonary resuscitation strategy and principles were proposed as below; this was based on experience in the rescue of explosive severe infectious diseases including Ebola virus infection in Africa, Middle East respiratory syndrome and RASA, and cardiopulmonary resuscitation in cardiac arrest, in combination with prevention and cardiopulmonary resuscitation of cardiac arrest as well as the fundamental theory and principle on cardiopulmonary resuscitation for severe infectious diseases.

1. Mortality of novel coronavirus pneumonia and current causes of death

Among the 6 coronaviruses that have infected humans in the past 20 years, the coronavirus causing explosive and highly infectious diseases with high morbidity and mortality include SARS virus (SARS-CoV) in 2003, which infected 8,096 patients, caused the death of 774 patients, and had the mortality of 9.6% and infection rate of 21.07% in health care personnel (HCP); Middle East Respiratory Syndrome virus (MERS-CoV) in 2012-2015, which infected 2,374 patients, caused the death of 837 patients, and had the mortality of 34.7% and infection rate of 19-21% in HCP; and the novel coronavirus (SARS-CoV-2) pneumonia that started in Wuhan, China, in December 2019 and is considered as the seventh coronavirus that infects humans. In accordance with the latest epidemiological and clinical study reports, the number of patients infected and dead in China were 74,576 and 2,118 by February 20, 2020 respectively, indicating a mortality rate of 2.3%-2.5% and the infection rate **(**on-duty and off-duty infection) was 3.8-4.0% in HCP. Although the mortality of novel coronavirus pneumonia was not as high as that of SARS and MERS, the base of infected patients and cumulative number of dead patients were high; in human coronavirus infection series, the number of patients infected with novel coronavirus pneumonia and cumulative number of dead patients have been ranked in the high-order section [2-10].

The cause of death from coronavirus pneumonia mainly included the following three categories based on the currently available clinical study report:

(1) Multiple organ failure: concurrent respiratory failure, circulatory failure, and renal failure, particularly in elderly patients with underlying diseases.

(2) Sudden cardiac arrest: sudden cardiac arrest although having stable vital signs (regardless of organ function support); patient died after resuscitation failure.

(3) Sudden exacerbation of condition: sudden exacerbation of symptoms during stable condition or improvement of condition, including rapid deterioration of respiratory function, sudden cardiac dysfunction, sudden circulatory failure, leading to cardiac arrest and death.

2. Prediction, prevention, and early warning of cardiac arrest in patients with novel coronavirus pneumonia

2.1 On the basis of the above three main causes of deaths from novel coronavirus pneumonia, the capability of Modern Critical Medicine has been mainly relied on for the first category of death in elderly patients with underlying disease and concurrent multiple organ failure in order prevent or reduce the occurrence of multiple organ failure as much as possible and to use various organ function support technologies after the occurrence. Targeted prediction, prevention, and

early warning measures were particularly needed to prevent the pathophysiological abnormalities of peri-arrest state, and early recognition and intervention were needed to reduce the incidence of cardiac arrest and to enable return of spontaneous circulation (ROSC) and survival discharge rate after the occurrence for the second and third categories of cause of death.

Early warning and early correction of the pathophysiological abnormalities in the peri-arrest state or pathophysiological abnormalities in the pre-arrest state can play an important role in the prevention and cardiopulmonary resuscitation of cardiac arrest; once cardiac arrest occurred, ROSC and the survival discharge rate were low despite conducting high-quality cardiopulmonary resuscitation. This was also a challenge faced by international cardiopulmonary resuscitation medical community. The success rate of cardiopulmonary resuscitation and the avoidance of infection in health care personnel were also challenges while conducting cardiopulmonary resuscitation by the health care personnel wearing three-level protective clothing under limited space, limited medical staff to patient ratio, and specific environment for cardiac arrest in patients with explosive and highly infectious diseases, such as novel coronavirus pneumonia.

2.2 Early warning of the causes of cardiac arrest in patients with novel coronavirus pneumonia. In case of no outbreak of epidemic situation, the cause of out-of-hospital cardiac arrest (OHCA) was 70%-80% cardiogenic, particularly in patients with acute myocardial infarction; the main causes of in-hospital cardiac arrest (IHCA) were hypoxemia/respiratory failure, shock and cardiac causes. Except multiple organ failure, the cases of sudden cardiac arrest in in-patients who died due to novel coronavirus pneumonia were associated with the following factors: (1) sudden exacerbation of condition, particularly impaired lung oxygenation leading to respiratory failure and inadequate time for tracheal intubation, invasive respiratory support or ineffective respiratory support; (2) sudden exacerbation of myocardial injury resulting from various reasons, including viral myocarditis and anoxia, leading to acute cardiac failure and serious arrhythmia; (3) sepsis and cardiogenic shock. Therefore, the following prediction, prevention and early warning measures for cardiac arrest have been proposed [11-13]:

High attention to respiratory function, including pulmonary CT image, respiratory rate, pulse oxygen and blood gas analysis; recognition of lung injury and respiratory failure and prevention of exacerbation of injury as early as possible; once lung injury, decreased PaO2/FiO2, and respiratory failure occurred, the possibility of cardiac arrest should be considered as a warning, and oxygen therapy at all levels should be started immediately, including noninvasive ventilation, invasive ventilation, correction of respiratory failure; and priority strategy of tracheal intubation

and invasive mechanical ventilation should be used to prevent the occurrence of cardiac arrest.

(1) Recognition of myocardial injury as early as possible, including monitoring of myocardial enzyme, cardiac function and arrhythmia; prevention of acute heart failure and malignant arrhythmia, attention paid to avoid use of drugs that may aggravate or affect cardiac function and arrhythmia; once pathophysiological abnormalities in the pre-arrest state occurred, such as acute heart failure, serious arrhythmia and shock, the possibility of cardiac arrest should be considered as warning, and various corrective and supportive measures for critical illness should be taken as much as possible as to prevent the occurrence of cardiac arrest.

(2) Recognition of other critical indicators for cardiac arrest as early as possible, e.g., septic shock, renal failure, internal environment disturbance, fluid overload.

3. Cardiopulmonary resuscitation strategy for cardiac arrest in novel coronavirus pneumonia

Relative to the cardiopulmonary resuscitation procedure for OHCA , there were corresponding strategies and procedures for cardiopulmonary resuscitation for the different causes of cardiac arrest in patients with novel coronavirus pneumonia and resuscitation environment.

3.1 Cardiopulmonary resuscitation strategy for out-of-hospital cardiac arrest (OHCA)

Out-of-hospital environment included household, work unit, social public area, and other non-medical area; in such places, the basic life support CPR is always provided by non-medical staff, which primarily includes chest compression, mouth-to-mouth ventilation and defibrillation with Automated External Defibrillator (AED); mouth-to-mouth ventilation is not suitable as patients with novel coronavirus pneumonia are highly contagious; therefore, the following measures are recommended [14-17]:

- Chest compression + defibrillation with AED (when necessary)
- Chest compression + active abdominal compression-decompression instrument (device) + AED (when necessary)

Personnel specially trained in active abdominal compression-decompression instrument (device) can use this device to establish abdominal respiration to replace chest respiration, until the arrival of healthcare professionals.

3.2 Cardiopulmonary resuscitation strategy during vehicle transportation

As the cardiopulmonary resuscitation provider are unable to stand properly during vehicle

movement, leading to inadequacy to provide high-quality chest compression and when the provider has insufficient physical strength to maintain high-quality cardiopulmonary resuscitation with hands, it is recommended to use mechanical cardiopulmonary resuscitator to replace manual chest compression.

3.3 Cardiopulmonary resuscitation strategy for in-hospital cardiac arrest

Cardiac arrest in patients with novel coronavirus pneumonia mostly occurred in medical institutions and mainly occurred in severe or critically ill patients in isolation ward or ICU; given the pathophysiological abnormalities in the peri-arrest state in patients with novel coronavirus pneumonia, high infectivity of the disease, high-concentration pathogen environment, nonprofessional medical worker to patient ratio and the features of protective measures for health care personnel, the cardiopulmonary resuscitation strategy and procedure for in-patient cardiac arrest in patients with novel coronavirus pneumonia are recommended as below:

The following principles and strategies are recommended for cardiopulmonary resuscitation technique and procedures [18-22]:

- Protective measures for Class A infectious diseases: the highest level of protective measures against infectious diseases were taken for resuscitation personnel (three-level protection, including full-face protection for respiration).
- Emergent endotracheal intubation: endotracheal intubation of the patients was performed under the guidance of fibrobronchoscope or visual laryngoscope and under sedative state.
- Chest compression : mechanical cardiopulmonary resuscitation could be used to replace manual chest compression, particularly in cases of insufficient resuscitation personnel and physical collapse, in order to avoid decreased quality of chest compression and increased infection chances induced by accidental entry of pathogenic sweat into the conjunctiva and nasal-oral mucosa of the cardiopulmonary resuscitation provider due to sweating from fatigue.
- Cardiopulmonary resuscitation for 30 minutes: in accordance with the cause of cardiac arrest as well as the mechanism of the disease injury and number of cardiopulmonary resuscitation provider, in combination with ethical factors, discontinuation of cardiopulmonary resuscitation could be considered after cardiopulmonary resuscitation for more than 30 min with no ROSC (no any vital sign present during cardiopulmonary resuscitation; except under the support of ECMO and extracorporeal circulation) (see the algorithm for warning and cardiopulmonary resuscitation for cardiac arrest in patients with novel coronavirus

pneumonia).

Note

1. **Highest level of protection against infectious diseases for the resuscitation provider，with three-level of protection including fluid-resistant gown, gloves, eye protection, full-face shield, N95 respirators, hair cover, hood and PAPR (powered air purifying respirators).**
2. **ROSC (return of spontaneous circulation)**
3. **ECMO (extracorporeal membrane oxygenation)**

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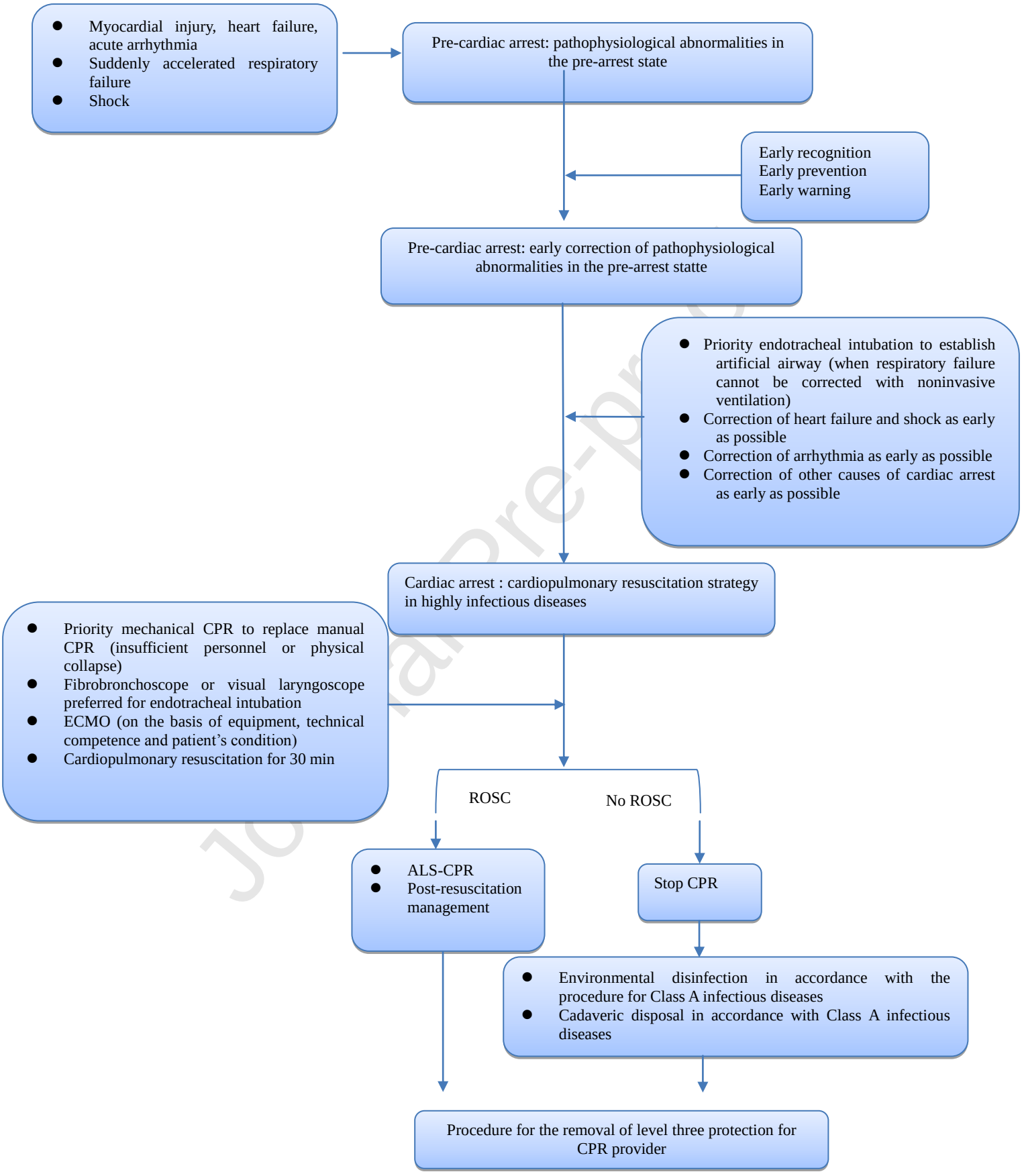
Algorithm for warning and cardiopulmonary resuscitation for cardiac arrest in patients with novel coronavirus pneumonia



No Conflict of Interest.