Consensus

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Expert consensus on prevention and cardiopulmonary resuscitation for cardiac arrest in COVID−19

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ABSTRACT

Background: Cardiopulmonary resuscitation (CPR) strategies in COVID-19 patients differ from those in patients suffering from cardiogenic cardiac arrest. During CPR, both healthcare and non-healthcare workers who provide resuscitation are at risk of infection. The Working Group for Expert Consensus on Prevention and Cardiopulmonary Resuscitation for Cardiac Arrest in COVID-19 has developed this Chinese Expert Consensus to guide clinical practice of CPR in COVID-19 patients.

Main recommendations: 1) A medical team should be assigned to evaluate severe and critical COVID-19 for early monitoring of cardiac-arrest warning signs. 2) Psychological counseling and treatment are highly recommended, since sympathetic and vagal abnormalities induced by psychological stress from the COVID-19 pandemic can induce cardiac arrest. 3) Healthcare workers should wear personal protective equipment (PPE). 4) Mouth-to-mouth ventilation should be avoided on patients suspected of having or diagnosed with COVID-19. 5) Hands-only chest compression and mechanical chest compression are recommended. 6) Tracheal-intubation procedures should be optimized and tracheal-intubation strategies should be implemented early. 7) CPR should be provided for 20-30 min. 8) Various factors should be taken into consideration such as the interests of patients and family members, ethics, transmission risks, and laws and regulations governing infectious disease control.

Changes in management: The following changes or modifications to CPR strategy in COVID-19 patients are proposed: 1) Healthcare workers should wear PPE. 2) Hands-only chest compression and mechanical chest compression can be implemented to reduce or avoid the spread of viruses by aerosols. 3) Both the benefits to patients and the risk of infection should be considered. 4) Hhealthcare workers should be fully aware of and trained in CPR strategies and procedures specifically for patients with COVID-19.

KEYWORDS: SARS-CoV-2; COVID-19; Cardiac arrest; CPR; Nosocomial infection; Personal protective equipment

1. Introduction

Of the six previous coronavirus (CoV) epidemics in the last 20 years, those with the highest rates of infection, morbidity, and mortality have been severe acute respiratory syndrome (SARS, caused by SARS-CoV) in 2003 (mortality rate, 9.6% and infection rate, 21.07% among healthcare workers[1]; Middle East respiratory syndrome (MERS, caused by MERS-CoV) in 2012-2015 (mortality rate, 34.7%[2] and infection rate, 13.37%-20.5% among healthcare workers[3,4]; Coronavirus 2019 (COVID-19, caused by SARS-CoV-2), which is prevalent in >200 countries worldwide. SARS-CoV-2 is the seventh coronavirus pandemic, with 112 209 815 confirmed cases as reported by the World Health Organization (WHO); its death toll as of March 25, 2021 was 2 490 776 (mortality rate, 2.2%)[5]. The overall infection rate among healthcare workers in this pandemic has

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been 10.1% (mortality rate, 0.3%)[6-8]. Although the current mortality rate of COVID-19 is lower than that of either SARS or MERS, the cumulative numbers of infected patients and deaths are much greater. Some deaths have occurred due to cardiac arrest. Cardiopulmonary resuscitation (CPR) and related procedures constitute one of the main contributors to the high infection rate among healthcare workers[8-10]. By March 1, 2020, some national and/or regional academic associations had issued guidelines, interim guidelines, or expert consensuses on CPR in COVID-19 patients[11-13]. Based on a review of recent literatures (including articles published in Chinese) and internationally issued guidelines for CPR in COVID-19, this Consensus puts forward the recommendations of Chinese experts on CPR in COVID-19 patients. The primary objective for developing this expert Consensus was to provide healthcare workers with updated insights into how to predict and prevent cardiac arrest in COVID-19 patients and avoid contracting the infection by implementing appropriate CPR strategies. Differences in special age categories (children), gender, and race were not considered in this Consensus.

2. Methods

2.1. Literature retrieval and data sources

A literature search was performed using the following database: PubMed, ClinicalKey, Embase, Cochrane Library, and Wanfang Med (Chinese) databases, in addition to WHO announcements. Studies that were published in English or Chinese between January 1, 2003, and March 24, 2021 were included for eligibility. The following keywords both in Chinese and English were used: "nosocomial infection", "SARS", "MERS", "COVID-19", "cardiac arrest", "CPR", "personal protective equipment", and "PPE". A total of 194 articles were collected, and 93 were selected and cited in this Consensus (Figure 1) which primarily focus on SARS, MERS, and the ongoing COVID-19 pandemic, as well as cardiac arrest, CPR, and PPE worn by healthcare workers during resuscitation.

2.2. Organizational structure of the expert Consensus development group

Forty-five members of the Consensus panel deliberated the following five topics: (1) methods for developing consensus, (2) causes and prevention of cardiac arrest in COVID-19, (3) COVID-19 CPR PPE, (4) COVID-19 CPR strategies, and (5) literature retrieval and evaluation. Members were divided into five groups, with several subgroups responsible either for writing drafts or serving as external expert reviewers. The experts in the Consensus development group were from the following research fields: emergency and critical-care medicine, infectious and respiratory diseases, nosocomial-infection control, ethics, hospital management, evidence-based medicine, and guideline development.

Members of the Consensus panel were appointed by the panel co-chairs and chosen based on their clinical experience and expertise in patient management, translational and clinical science, and/or development of treatment guidelines. Panel members included representatives from academic organizations and professional societies; those represented on the panel were as follows: (1) Committee of Cardiopulmonary Resuscitation, Chinese Research Hospital Association, (2) Chinese College of Emergency Physicians, (3) Chinese Society of Emergency Medicine, (4) Chinese Society of Critical Care Medicine, (5) Chinese Society of Disaster Medicine, (6) Chinese Society of Respiratory Diseases, and (7) Hospital Infection Management Committee of the Chinese Hospital Association. The inclusion of representatives from these professional societies does not imply that their societies endorsed the Consensus.

Table 1. Evidence levels and strengths of recommendation.

Evidence level and strength of recommendation	Description
Evidence level	
Level Ⅰ (high level)	High-quality randomized controlled trial (RCT), authoritative guideline, high-quality systematic review, and meta-analysis
Level Ⅱ (moderate level)	RCT study with certain limitations (*e.g.*, no control group, no blinding, no report of loss of follow-up), cohort study, and case-control study
Level Ⅲ (low level)	Case series study, case report, expert opinion, and *in vitro* drug sensitivity study on antibacterial drugs without clinical data
Strength of recommendation	
A (strongly recommended)	This regimen should be adopted by most patients, medical staff, and policy makers.
B (moderately recommended)	This regimen can be adopted by most but not all patients, medical staff, and policy makers; decision makers should take into account the values and wishes of patients according to specific conditions.
C (weakly recommended)	Lack of evidence and decisions can only be made after discussion by patients, medical staff, and policymakers.

2.3. Evidence levels and strengths of recommendation

The retrieved articles included randomized controlled trials (RCTs), cohort studies, retrospective studies, and review articles on mortality, causes of cardiac arrest, nosocomial-infection rates in healthcare workers, peri-cardiac arrests, abnormal early-warning signs, and CPR strategies during pandemics (especially in the early stages). These articles were separately analyzed and evaluated based on 32 proposed clinically related questions. A Grades of Recommendation, Assessment, Development and Evaluation (GRADE) consensus was compiled in accordance with clinical guidelines, evidence levels, and strengths of recommendation[14,15], leading to 28 promulgated recommendations. Evidence levels and strengths of recommendation are presented in Table 1.

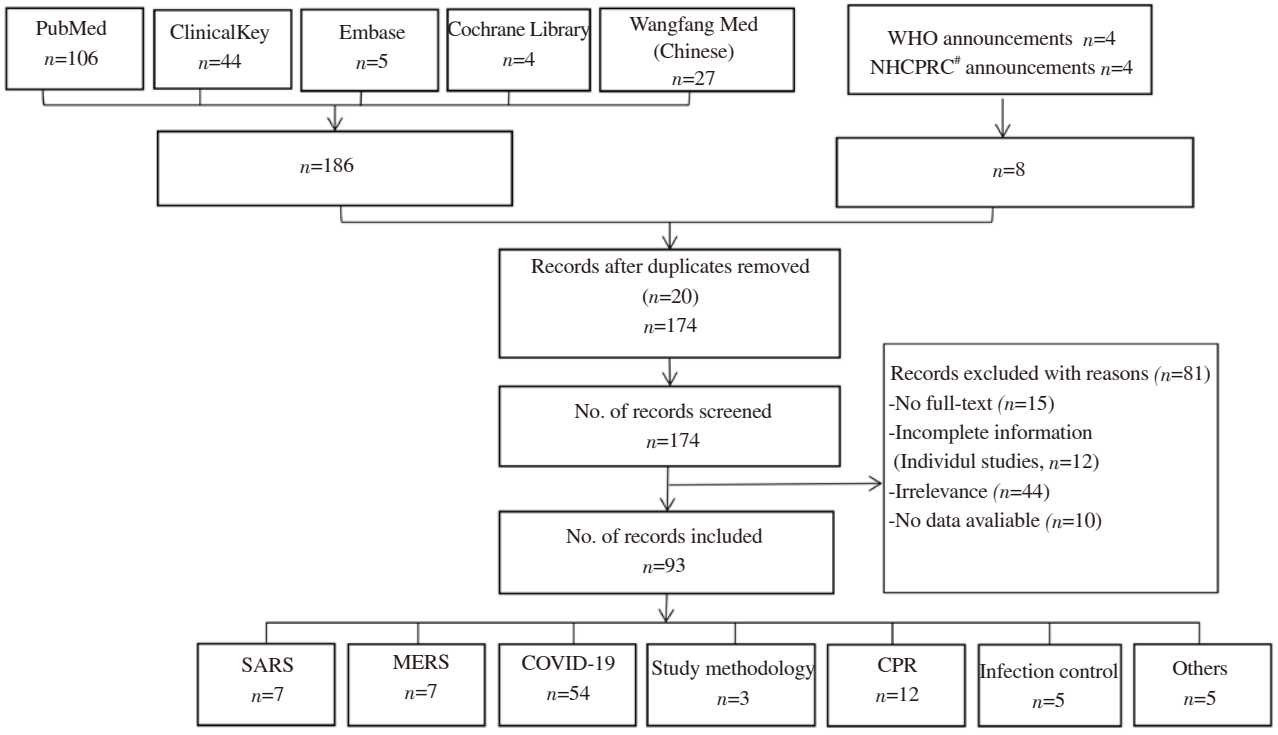

Figure 1. Flowchart of literatuer selection. # NHCPRC: National Health Commission of the People's Republic of China.

2.4. Delphi vote

Given the small number of Level Ⅰ evidence articles dealing specifically with coronavirus infection and CPR, evidence-based medicine combined with the guidelines was used to develop the expert Consensus. After deliberation by experts during three video conferences, the 28 recommendations were selected using the Delphi voting method[16] and ranked as (1) strongly recommended, (2) moderately recommended, or (3) weakly recommended. Opinions were formally proposed when they reached 75% expert consensus, while recommended opinions that did not reach 75% consensus were deleted or not proposed as formal recommendations.

3. Cardiac arrest in COVID-19 patients: Precognition, prevention and early-warning signs

3.1. Inducing (risk) factors for death in COVID-19 patients

3.1.1. Acute respiratory failure

The lungs are the primary organs that are injured by COVID-19 infection. Such injury can result in increased lung secretions and thick sputum obstructing the small airways, which causes acute respiratory-distress syndrome (ARDS) and finally leads to respiratory failure. Respiratory failure can intensify quickly and is often irreversible and fatal[17,18]. Decreased oxygenation indices and dyspnea appear 5-7 days after the onset of COVID-19[19], while the rate of respiratory failure is 6.7%-12%[20].

3.1.2. Acute cardiovascular events

The heart is another target organ of COVID-19. Cardiac infection leads to acute cardiac insufficiency, myocardial conduction system dysfunction, arrhythmia, acute myocardial infarction (MI), and exacerbation of underlying cardiovascular diseases (CVDs)[21]. Case reports showed that more than half of deceased patients had increased levels of cardiac troponin Ⅰ, a marker of cardiac injury[18]. COVID-19 patients with hypertension, cardiac insufficiency, or other serious underlying diseases were more likely to die of heart and multiple-organ failure.

3.1.3. Cardiac arrest

Patients who stabilize can, nonetheless, experience sudden cardiac arrest. Cardiac arrest can occur because of respiratory failure and cytokine storm, which exacerbates respiratory, circulatory, and multiple-organ failure as well as cardiac arrest. Sudden cardiac arrest in COVID-19 patients are also reported[21-23].

3.1.4. Other serious complications and inducing factors

Pulmonary embolism, acute renal failure, malignant arrhythmia, electrolyte disorder, drug-related cardiac toxicity, and panic psychosis are associated with cardiac arrest in COVID-19

patients[24]. Patients with severe COVID-19 often have coagulation disorders. Prothrombin and *D*-dimer levels are significantly elevated in COVID-19 patients in the intensive-care unit (ICU) compared with non-ICU patients: in one study, 36% of patients admitted for COVID-19 had *D*-dimer levels >1 500 μg/L. Furthermore, coagulation disorders and *D*-dimer levels >1 μg/mL are reported to correlate with death outcomes in COVID-19 patients[18,25,26].

3.1.5. Risk factors for death in COVID-19 patients

Diabetes, neurological disorders, hypertension, renal disease, cancer, anemia, obesity, congenital abnormalities, hepatobiliary disease, and use of steroids are risk factors for death in COVID-19. High sequential organ failure assessment (SOFA) score and older age are also potential risk factors[27].

3.2. Awareness, prevention, and early-warning signs of cardiac arrest in COVID-19 patients

3.2.1. Early awareness of severe and critical types of COVID-19

In accordance with Diagnosis and Treatment of Novel Coronavirus Pneumonia[28] (Trial Version 7, released by the National Health Commission of the People's Republic of China), death is primarily seen in severe and critical cases of COVID-19 (the four defined types are mild, common, severe, and critical). Therefore, awareness, prevention, and early-warning measures of the severe and critical types are important to reducing cardiac arrest and mortality in COVID-19[29].

Dynamic awareness is defined as comprehensive observation of COVID-19 patients' conditions and a traceable evaluation of cardiac-arrest risk[30]. Traceable awareness refers to identification of the inducing and risk factors that could lead to cardiac arrest and death in these patients. Preventive measures should be taken, especially if the patient has chronic underlying diseases.

3.2.2. Prevention of cardiac arrest in COVID-19 patients

Early correction of pathophysiological changes play an important roles in the prevention of cardiac arrest. However, once cardiac arrest occurs, even if high-quality CPR is performed, return of spontaneous circulation (ROSC) is unlikely and survival rate is low.

3.2.3. Early-warning signs of cardiac arrest in COVID-19 patients

Under normal circumstances, the most common cause of cardiac arrest is cardiogenic (70%-80% cases) and often involves acute MI. To prevent cardiac death in hospitalized COVID-19 patients, the following predictive, preventive, and early-warning measures are recommended (Table 2)[31-34].

Table 2. Early warning of cardiac arrest in COVID-19 patients and management.

Early warning	Management
Respiratory:	
Respiratory rate ⩾30 times/min Oxygenation index⩽300 mmHg Blood oxygen⩽ 93%	Give oxygen therapy (high-flow oxygen, non-invasive ventilation, and invasive ventilation); conduct rapid sequence intubation with video guided laryngoscopy; conduct tracheal intubation (experienced practitioners); ongoing management under a dedicated airway team.
Circulation:	
Acute heart failure Malignant arrhythmia Shock	Correct heart failure and malignant arrhythmia; give antishock therapy; avoid use of drugs that suppress cardiac function and/or promote arrhythmia
Inflammatory stress markers:	
Significantly increased CRP, PCT, ferritin, and *D*-dimer Significantly increased total lymphocyte counts, cytokines IL-4, IL-6, IL-10, TNF-α, and INF-γ	Dynamic monitor of vital organ function
Severity and critical warning:	
Assessing severe and critical types	Use CURB-65, PSI, qSOFA, and SOFA tools; Assign a medical team specialized in regular assessment of patients with severe and critical types

CRP: C-reactive protein; PCT: procalcitonin; IL: interleukin; TNF-α: tumor necrosis factor alpha; INF-γ: interferon gamma; PSI: Pneumonia Severity Index; SOFA: Sequential Organ Failure Assessment; qSOFA: Quick SOFA.

Recommendation 1: Prioritize the monitoring of respiratory function, including respiratory rate (RR), blood oxygen saturation (SpO_2), arterial-blood gases (ABGs), and computed-tomography (CT) chest scan (Level Ⅰ evidence, highly recommended).

Once RR exceeds 30/min, oxygenation index (OI) is <300 mmHg, and blood oxygen level falls below 93%, cardiac arrest is imminent. To correct respiratory failure, oxygen therapy should be given, including high-flow oxygen, non-invasive ventilation, and invasive ventilation[35].

Recommendation 2: Identify myocardial injury and circulatory deterioration at the early stage; and monitor myocardial-enzyme levels, cardiac-function indicators, occurrence of arrhythmias, and hemodynamic and shock indicators (Level Ⅱ evidence, moderately recommended).

Patients should be monitored to identify malignant arrhythmia, decreases in effective blood volume, and circulatory failure. Drugs that suppress cardiac function and/or promote arrhythmia should be avoided. Peri-cardiac arrest is associated with pathophysiological abnormalities that include acute heart failure, malignant arrhythmia, and shock, particularly septic shock. These are warning signs of immediate cardiac arrest, and corresponding critical-care measures should be initiated.

Recommendation 3: Evaluate clinical progression early by screening for severe and critical symptoms to take appropriate measures (Level Ⅱ evidence, moderately recommended).

Tracking of inflammatory-stress markers, including C-reactive protein (CRP), procalcitonin (PCT), ferritin, and *D*-dimer levels; total lymphocyte counts; and concentrations of the cytokines interleukins-4, -6, and -10 (IL-4, IL-6, IL-10), tumor necrosis factor alpha (TNF-α), and interferon gamma (INF-γ), is recommended. CT chest scan should be performed within 24 h, and dynamic monitoring of vital organ functions is recommended[36,37].

Recommendation 4: Enhance airway management, prevent airway events, and reduce viral environmental pollution (Level Ⅱ evidence, moderately recommended).

COVID-19 patients have abundant secretions in their small airways, which are easily obstructed by thick sputum. A sputum bolt should be avoided. Airway and ventilator-related injury secondary to mechanical ventilation should be prevented. During sputum aspiration and non-invasive ventilation, emission of droplets and aerosols can occur when the respirator is disconnected; therefore, the above procedures should be completed in a negative-pressure ward to reduce the risk of pathogen dissemination[38–42]. A closed method of sputum aspiration can be used. Mechanical trauma to the airways should be avoided, as it can promote mucosal edema, inflammation, and hemorrhage[40,41]. In line with this, negative-pressure sputum aspiration should be performed for 15 s at the longest[42].

Airway management strategies for COVID-19 patients should include: (1) the use of rapid-sequence intubation with video laryngoscopy rather than direct laryngoscopy; (2) tracheal intubation conducted by experienced practitioners to increase the first-pass success rate; and (3) ongoing management provided by a dedicated airway team[43].

Recommendation 5: Recognize other factors and clinical findings that contribute to cardiac arrest and peri-cardiac arrest in a timely fashion (Level Ⅲ evidence, weakly recommended).

Close monitoring of the functions of other organs and of physiological irregularities, such as electrolyte abnormalities, abnormal acid-base balance, fluid balance, and deep-vein thrombosis, is recommended. Abnormalities in these critical parameters could lead to peri-cardiac arrest.

Recommendation 6: Assign a medical team to evaluate patients with severe and critical COVID-19 and identify warning signs of cardiac arrest at the early stage (Level Ⅲ evidence, weakly recommended).

A medical team specializing in assessing patients with severe and critical COVID-19 should be assigned. Based on the patient's underlying diseases and COVID-19 progression, the patient should be evaluated twice daily. The CURB-65, Pneumonia Severity Index (PSI), Sequential Organ Failure Assessment (SOFA), and Quick SOFA (qSOFA) tools should be employed along with SpO_2, RR, heart rate (HR), and blood pressure (BP); and abnormalities should be corrected[39].

Recommendation 7: The hospital management team should design procedures to detect warning signs of cardiac arrest in COVID-19 patients at the early stage and establish safe procedures for performing CPR in the event of cardiac arrest (Level Ⅲ evidence, weakly recommended).

The hospital management team should establish a protocol to detect early signs of cardiac arrest in high-risk COVID-19 patients and should report the statuses of those patients on a regular basis. Healthcare workers should be trained in and apply best practices for treating cardiac arrest and conducting CPR while wearing PPE[44].

4. Personal protection of medical personnel

4.1. Personal–protection levels for healthcare workers treating COVID–19

COVID-19 is a highly infectious disease. Identified routes of transmission include droplets, direct contact, and aerosols[25,45,46]. Standard principles for the prevention of infectious diseases should be applied to protect healthcare workers treating COVID-19 patients. Isolation protocols should be imposed to avoid contact, droplets, and aerosolized virus. All healthcare workers should have appropriate PPE based on the three-level personal-protection standards (Table 3)[47–52].

4.2. CPR protection and optimization strategy in COVID–19 patients

Infection of CPR resuscitation personnel has been reported worldwide[53]. For infectious diseases, in particular those transmitted by droplets and aerosols, performing CPR-related procedures increases the healthcare worker's risk of infection. During the global pandemics of SARS in 2003 and MERS in 2012-2015, infection occurred in healthcare workers performing CPR, even if PPE was available[10,13,54].

During the COVID-19 pandemic, the infection rate among healthcare workers has been related to the risk of the procedure and the personal-protection level enforced. Specifically, higher risk, especially with insufficient personal protection, was associated with higher infection rates. Unfortunately, as this pandemic began, there was a shortage of PPE, which led to nosocomial-acquired infections[55,56]. Healthcare workers should wear PPE in accordance with the conditions at their hospital.

The following personal protective strategies have been optimized and are recommended for emergency management of peri-cardiac

Table 3. Three-level PPE for healthcare workers and their application in COVID-19 management.

Protection level	Place of use and operation	Risk of infection	Surgical mask	N95	Face shield/ safe goggles	Positive pressure head cover	Gloves	Gown	Protective cap	Shoes or boot cover
Level Ⅰ protection	1. Pre-triage	Moderate risk								
	2. Fever clinic	Moderate risk	+	±	±	-	±	±	+	-
	3. Emergency resuscitation room*	Moderate-high risk								
Level Ⅱ protection	1. Fever clinic for COVID-19	High risk	-	+	±	-	+†	±‡	+	+
	2. Collecting specimens from COVID-19 patients, processing their secretions and excretions, contacting with the objects used by the patients	High risk								
	3. Handling COVID-19 patients in isolation wards	High risk								
Level Ⅲ protection	1. Conduction of a procedure that can cause aerosol transmission, *e.g.*, non-invasive positive pressure mechanical ventilation, tracheal intubation, aerosol therapy, use of bronchoscope	Very high risk	-	+	+	+§	+†	+	+	+
	2. Cardiopulmonary resuscitation	Very high risk								

"+" protective appliances to be worn, "-" protective appliances not required to be worn, "±" protective appliances to be worn as required by work, "*" large number of COVID-19 patients may be crowded in the emergency room during the outbreak of COVID-19, the personal protection level should be improved to levels Ⅱ or level Ⅲ. "+†" double gloves required, and it is advised to wear nitrile glove as the outer glove in level Ⅲ protection, "±‡" isolation gown or protective clothing chosen to wear based on the actual condition at the medical institution in level Ⅱ protection, "+§" replacement of medical protective masks and goggles/face shields with comprehensive or higher-level electric air supply filter respirator if the condition allows in level Ⅲ protection.

arrest, pathophysiological abnormalities, and CPR in patients with suspected or confirmed COVID-19:

Recommendation 8: Healthcare workers should conduct CPR under Level Ⅲ personal protective conditions (Level Ⅰ evidence, strongly recommended).

CPR involves risk of viral transmission through droplets, direct contact, and aerosol diffusion. To avoid infection, CPR should be conducted under Level Ⅲ personal protective conditions[49].

Recommendation 9: Use CPR equipment specially designed for patients with COVID-19 to reduce contamination of the equipment[48–50] (Level Ⅰ evidence, strongly recommended).

Recommendation 10: Supervise wearing and removal of PPE by the infection control team when they enter and exit the isolation resuscitation room and ICU[57,58] (Level Ⅲ evidence, weakly recommended).

Recommendation 11: For defibrillation, use a multifunction defibrillator with pre-attached electrodes (Level Ⅲ evidence, weakly recommended).

A report on CPR training for cardiac arrest in SARS recommended a multifunction defibrillator with pre-attached electrodes. The defibrillator should be placed 2 m from the patient to reduce the risk of equipment contamination[59].

Recommendation 12: Minimize the flow of healthcare workers into and out of the room during CPR and limit their number to four if possible (Level Ⅲ evidence, weakly recommended).

The number of healthcare workers performing CPR should be controlled. Moreover, healthcare workers should maintain a distance of at least 2 m from patients if Level Ⅲ PPE is not accessible. Sufficient essential resuscitation drugs and disposables should be prepared to reduce the flow of healthcare workers into and out of the room[59–61].

Recommendation 13: Resuscitation should be carried out in isolation rooms, COVID-19 ICUs, or negative-pressure wards; and the air should be circulated 12/h to improve the air exchange rate and reduce the risk of nosocomial infection[62, 63] (Level Ⅰ evidence, strongly recommended).

5. CPR strategy for cardiac arrest in COVID-19 patients

Compared with cardiac arrest in noninfectious diseases, cardiac arrest in COVID-19 patients is characterized by a different etiology, different resuscitation environment, high infectivity, pandemic conditions, high mortality, and risk of healthcare personnel infection during CPR. CPR strategies and procedures for COVID-19 patients should be performed in accordance with the three principles of standardization, diversification, and individualization in order to maximize ROSC and survival discharge rate in these patients[64].

5.1. Peri-cardiac arrest early-warning signs and management in COVID-19

The peri-cardiac arrest period in COVID-19 is defined as the early stages of cardiac arrest, when clinical early-warning signs are evident and urgent intervention is needed. A series of preventive, precognitive, and early-warning measures should be taken in response to the primary cause, primary inducing factors, and primary high-risk factors of cardiac arrest in COVID-19 patients; the "three pre" strategy is important to prevent cardiac arrest and reduce mortality in COVID-19 patients.

5.1.1. Prevention, early recognition, and management of respiratory failure in the early stages of cardiac arrest in COVID-19 patients

Cardiac arrest in COVID-19 primarily results from ARDS, hypoxemia, and respiratory failure induced by lung injury and small-airway obstruction. Active oxygen therapy, assisted ventilation, airway protection, reinforced sputum excretion, and airway management are needed[65]. An early tracheal-intubation strategy should be initiated for respiratory failure refractory to less-invasive measures. Patients should be monitored for tension pneumothorax and pulmonary embolism.

5.1.2. Prevention, early recognition, and management of cardiovascular events in COVID-19 patients

COVID-19 can infect cardiovascular (CV) tissues and cause localized or diffuse acute myocardial disease, leading directly to cardiac arrest. COVID-19 infection of the heart manifests as fulminant myocarditis, thrombosis, and MI. Cardiac arrest occurs secondary to serious arrhythmia, acute heart failure, and cardiogenic shock in the acute phase, particularly in older patients with underlying CVDs. Some patients with severe COVID-19 develop cytokine storm, which promotes severe fulminant myocarditis and sudden cardiac arrest[66]. Close monitoring of the disease, timely antiarrhythmic therapy, correction of shock, and other interventions for early CV dysfunction are important to prevent cardiac arrest[67].

5.1.3. Prevention, early recognition, and management of non-cardiogenic and non-respiratory cardiac arrest in COVID-19 patients

High-risk elderly patients with COVID-19 can experience cardiac arrest because of underlying septic shock, acute renal failure, cerebral apoplexy, and concurrent CVD. Measures to prevent cardiac arrest should be taken, including correction of septic shock, increasing fluids, renal-replacement therapy, and prevention of multiple-organ failure.

5.1.4. Prevention, early recognition, and management of reversible cardiac arrest in COVID-19 patients

Recommendation 14: Sympathetic and vagal abnormalities induced by the psychological stress of crisis events can induce cardiac arrest. Psychological counseling and treatment are highly recommended (Level Ⅱ evidence, moderately recommended).

COVID-19 induced cardiac arrest is believed to occur in certain situations from the psychological stress of the crisis. These events are due to the internal and external changes in the body during COVID-19 infection[34,68]. This type of cardiac arrest might be prevented by psychological counseling for patients who face mental challenges.

5.2. CPR strategies for out-of-hospital cardiac arrest

Recommendation 15: The following CPR measures are recommended to avoid mouth-to-mouth resuscitation of patients with suspected or confirmed COVID-19: (1) hands-only chest compression+defibrillation with automatic defibrillator (if necessary)[69-72] (Level Ⅰ evidence, strongly recommended); and (2) hands-only chest compression + abdominal cardiopulmonary resuscitator + defibrillation with automatic defibrillator, if necessary (Level Ⅲ evidence, weakly recommended).

Outside the hospital, including in the home, workplace, and public areas, rescuers might be either medically trained personnel or those with no medical training. These settings pose a high possibility of infection during performance of CPR on patients with suspected or diagnosed COVID-19. Because of the suddenness of cardiac arrest, it is likely that nonmedical personnel might need to apply CPR, but they should be aware of the risks and wear PPE if available. Mouth-to-mouth breathing is not advised during CPR[29]. Medical personnel equipped and trained to use an abdominal-lifting cardiopulmonary resuscitator (also known as active abdominal compression-decompression CPR) can use this device, which can establish artificial circulation and abdominal respiration to replace chest breathing while avoiding exposure to the patient's airways so as to reduce the risk of contracting the infection[73,74]. If a healthcare worker arrives at the site and is equipped with a resuscitation balloon, this simple respirator can be used for ventilation. A highly efficient bacterial/viral filter should be placed between the respirator and the mask.

5.3. CPR strategies during ambulance transfer

Recommendation 16: Mechanical chest compression can be used to replace manual chest compression for CPR during ambulance transfer of patients with diagnosed or suspected COVID-19 (Level Ⅰ evidence, strongly recommended).

The ambulance staff should use a negative-pressure ambulance for patient transfer and wear Level Ⅲ PPE. Standing in a moving ambulance makes it difficult for the ambulance staff to adequately perform CPR, and it is also difficult to provide vigorous chest compression and maintain good manual CPR due to the inadequate number of resuscitating personnel. Therefore, a mechanical chest compression device can be used to replace manual chest compression[75,76].

5.4. CPR strategies for cardiac arrest in the hospital setting

There are inherent challenges to performing CPR on COVID-19 patients because of the high infection rate of the disease, the high concentration of pathogens in the environment, and the use of PPE by medical personnel. The main challenges are as follows: (1) inconvenience of using a stethoscope to confirm the position of tracheal intubation; (2) inconvenience of using a stethoscope to confirm recovery of heartbeat; (3) susceptibility to sweating in heavy protective clothing, and, if the PPE is breached or worn inappropriately, virus-infected sweat entering the conjunctiva and oral mucosa; (4) insufficient number of healthcare workers; and (5) decreased sensitivity of fingers due to double gloves, which affects the rapid establishment of venous access. Therefore, there must be multifaceted CPR strategies and procedures in the hospital setting for cardiac arrest in COVID-19 patients.

Recommendation 17: Hospitals are advised to prepare for COVID-19 cardiac arrests and resuscitation efforts by establishing and training tracheal-intubation teams and CPR teams (Level Ⅰ evidence, strongly recommended).

CPR personnel face the highest-level risk of infection and should use the highest level of personal protection. Tracheal-intubation and CPR teams of as few members as efficient should be established to specifically care for COVID-19 cardiac-arrest patients[65,77-80].

Recommendation 18: Within the ER, prepare a resuscitation/rescue room for infectious diseases that can be used for sudden cardiac arrest and CPR in patients with diagnosed or suspected COVID-19[29] (Level Ⅲ evidence, weakly recommended).

Recommendation 19: Optimize tracheal-intubation procedures and implement early tracheal-intubation strategies (Level Ⅱ evidence, moderately recommended).

In COVID-19 patients, early tracheal intubation and invasive positive-pressure ventilation should be considered when respiratory failure cannot be corrected *via* trans-nasal high-flow oxygen therapy or noninvasive mechanical ventilation. Intubation can be considered when there is progressive exacerbation of hypoxemia, dyspnea, distress, carbon dioxide retention ($PaCO_2$> 45 mmHg), or hemodynamic instability. If respiratory failure occurs, tracheal intubation should be performed early to avoid emergency intubation and sudden cardiac arrest[65,81,82].

The airway should be evaluated prior to intubation, with a reserve plan (*e.g.*, tracheotomy, laryngeal mask, or esophageal-tracheal combi-tube) in place in case tracheal intubation fails. A visual laryngoscope and fibrotic bronchoscope are recommended to guide tracheal intubation and to perform the procedure in sedated patients. In order to avoid the formation of aerosols or airborne transmission of virus, a highly efficient bacterial/viral filter should be used between the respirator and the mask. When mechanical ventilation is used, this type of filter should also be placed between the suction branch of the respiratory circuit and the respirator output, as well as between the exhalation branch and respirator exhalation port[81-84].

Recommendation 20: Use a lung-protective ventilation strategy (Level Ⅰ evidence, strongly recommended).

Once a good airway is established, medical personnel should use a lung-protective ventilation strategy (target tidal volume set at 6 mL/kg, platform pressure $\leqslant$30 cm H_2O, oxygen saturation as measured 88%-95%, pH 7.25)[57,81-85].

Recommendation 21: Use a device with a CPR feedback system and bedside ultrasound to guide CPR (Level Ⅰ evidence, strongly recommended).

Heavy PPE might affect the evaluation of CPR quality and the success of the resuscitation technique[86]. To achieve successful resuscitation, a device with a CPR feedback system that maximizes the quality of standard CPR should be used, such as an end-tidal carbon dioxide device. Bedsides, ultrasound should be used to confirm the position of tracheal intubation and allow for the rapid establishment of venous access in central veins.

Recommendation 22: Mechanical chest compression can be used to replace manual chest compression during CPR for COVID-19 patients (Level Ⅱ evidence, moderately recommended).

A mechanical-resuscitation device can provide sustained vigorous compression and avoid decreasing the quality of chest compression, especially when personnel or physical strength is insufficient. This avoids accidental flow of pathogen-contaminated sweat into the conjunctiva and oral mucosa of the healthcare worker. The risk of infection is increased if a breach in the protective clothing develops. The resuscitation team should be able to implement mechanical resuscitation quickly to shorten the time of compression interruption. Caution should be exercised in using a mechanical chest compression device on older patients to avoid fracture of the sternum and ribs[75,76,87].

Recommendation 23: Extracorporeal-membrane oxygenation (ECMO) can be implemented in combination with CPR (a procedure known as ECPR) if conditions allow (Level Ⅲ evidence, weakly recommended).

ECPR can be considered depending on the patient's condition. For COVID-19 patients, the timing of ECMO intervention should be prior to cardiac arrest. When respiratory failure cannot be corrected

with routine respiratory support, ECMO might be efficacious. Indications for ECMO intervention include the following: (1) FiO_2> 90% and OI < 80 mmHg for >3-4 h and/or combined with hypercapnia; (2) plateau pressure ⩾35 cm H_2O[88,89].

Recommendation 24: Provide CPR for 20-30 min (Level Ⅲ evidence, weakly recommended).

In accordance with the cause of cardiac arrest, level of disease damage, and number of personnel performing CPR, in combination with the ethical considerations of possible infection in resuscitating personnel, CPR should be performed for 20-30 min and discontinued when there is no return of spontaneous circulation nor any vital signs (apart from those occurring with ECMO and cardiopulmonary-bypass support)[11,90].

Recommendation 25: An abdominal-lifting cardiopulmonary resuscitator can be used for abdominal CPR when chest compression might fracture the sternum and ribs in patients of advanced age, and prone CPR can be used if patients are positioned prone (Level Ⅲ evidence, weakly recommended).

Older patients with concurrent underlying diseases present challenges for CPR, as they are prone to fracture of the sternum and ribs during chest compression. Once such fracture occurs, an abdominal-lifting cardiopulmonary resuscitator can be used for abdominal CPR when emergency thoracotomy resuscitation cannot be performed[74,91].

If the patient cannot be safely turned from a prone to a supine position, CPR can be provided with the patient remaining prone, with their hands in the position over the T7/10 vertebral bodies or between the scapulae (shoulder blades), at the depth and rate of 5-6 cm at 2 compressions per second, and with the defibrillator pads placed in the anterior-posterior position[92].

5.5. Ethical issues around CPR during the COVID-19 pandemic

Recommendation 26: CPR should not be avoided due to fear of COVID-19 infection. Healthcare workers should wear PPE for performing CPR. Unnecessary and ineffective CPR will increase the risk of infection in rescuers, which is not good for the patient[90] (Level Ⅲ evidence, weakly recommended).

Over the course of the pandemic, several new ethical issues related to COVID-19 patients and medical personnel have developed. When CPR is performed in cardiac arrest, many issues should be considered, including risk of infection to resuscitating personnel, lack of medical resources, resuscitation benefit-to-harm ratio for resuscitating personnel, and disposal of the remains if the procedure is not successful.

Recommendation 27: Cardiopulmonary resuscitating personnel are advised to withdraw CPR in the following conditions during the COVID-19 pandemic[90,93] (Level Ⅲ evidence, weakly recommended): (1) irreversible death, (2) exacerbation of the condition and inability to produce a benefit despite best efforts, (3) serious injury or infection to the rescuer with the continuation of CPR, (4) an effective "do not resuscitate" order, and (5) other conditions such as applying CPR for >20-30 min.

Recommendation 28: Local cultures, religions, and ethics must be considered and respected in the disposal of the patient's remains (Level Ⅲ evidence, weakly recommended).

Body disposal should be based on the principles for disposal of highly infectious remains. Namely, the remains should be covered with a double cloth sheet impregnated with disinfectant by specially trained personnel, put into a double-layer body bag, and sent in a specialized vehicle to a designated place for disposal[49].

Conflict of interest statement

The authors report no conflicts of interest among the members of the expert Consensus panel.

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Authors' contributions

All authors of this manuscript directly participated in the planning, execution, and analysis of the Consensus. Drs. W.S., J.W., and X.D.J. designed the Consensus; Dr. D.R.W. ran the study; Drs. S.M.X.Y. and X.B.C. handled nosocomial-infection control; Dr. S.J.X. dealt with ethics; Drs. W.S., Y.S.L., H.P.X., and F.Z. prepared the first draft of the manuscript, which was initially revised after input from the core writing group (Drs. Y.S.L., H.P.X., F.Z., X.J.D., Y.C., Q.N., X.L., T.E.Z., and S.A.Z.); Drs. L.W. and Y.F.Z. and Ms. Y.W. managed literature retrieval, evidence levels, and strengths of recommendations; and Ms. M.Y.L. conducted the Delphi surveys. These outputs were then circulated, discussed, and reviewed in detail with the co-authors, who added important intellectual content for the manuscript's refinement. All authors then approved the final version.

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