Heliyon 10 (2024) e32615

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Comparison of pre-hospital management of out-of-hospital cardiac arrest and its outcomes between the COVID-19 and pre-COVID-19 periods

Himan Maroofi [a], Kobra Akhoundzadeh [b,*], Hamid Asayesh [a]

[a] Department of Nursing, Qom University of Medical Sciences, Qom, Iran
[b] Department of Physiology, Qom University of Medical Sciences, Qom, Iran

ARTICLE INFO

Keywords:
Emergency medical services
Pre-hospital
Out-of-hospital cardiac arrest
COVID-19
Response time

ABSTRACT

Out-of-hospital cardiac arrest (OHCA) is a time-sensitive medical emergency that needs immediate interventions. COVID-19 affected the performance of the emergency medical service (EMS) system in pre-hospital care, including the management of cardiac arrest. This study aimed to identify the impact of the COVID-19 pandemic on pre-hospital management of out-of-hospital cardiac arrest and its outcome in Qom City, Iran. In this descriptive-analytical study, the data were collected from the electronic registration system of the EMS center in Qom, Iran. All OHCA patients who received resuscitation during COVID-19 and before COVID-19 were enrolled in the study. Data consisted of the characteristics of OHCA patients, EMS interventions and response times, and the outcome of OHCA. A P-value of <0.05 was deemed statistically significant. 630 OHCA patients in the COVID-19 period and 524 OHCA patients in the pre-COVID-19 period were included in the study. Endotracheal intubation and defibrillation were done more in the COVID-19 period than in the pre-COVID-19 period (50.2 % vs. 17 %, $p<0.001$ %, and 40.1 % vs. 22.5 %, $p < 0.001$, respectively). The EMS response time was longer during the COVID-19 pandemic (9.1 ± 3.9 min vs. 7.6 ± 1.4 min, $p < 0.001$). The rate of pre-hospital return of spontaneous circulation (ROSC) was lower in the COVID-19 period (15.6 % vs. 8.4 %, $p < 0.001$). According to univariate analysis, ROSC was predicted by COVID-19 ($p < 0.001$). However, COVID-19 was not the statistically significant independent predictor after multivariate analysis ($p < 0.67$). The COVID-19 pandemic period influenced OHCA and ROSC. Also, it affected pre-hospital management in the OHCA situation. The negative impact of COVID-19 on the EMS response reflected the need to know and remove barriers to managing crises such as COVID-19.

1. Introduction

Several unexplained pneumonia cases were initially reported in December 2019 in Wuhan, China. On February 11, 2020, the World Health Organization (WHO) officially named the disease caused by 2019-nCoV as coronavirus disease 2019 (COVID-19) and on January 30, 2020, announced the COVID-19 pandemic as a public health emergency of international concern [1]. In Iran, the first case of COVID-19 was reported on February 19, 2020, in Qom City [2].

The COVID-19 pandemic greatly impacted the global dimensions of public health [3]. According to current reports, there is a

* Corresponding author. Department of Physiology, Qom University of Medical Sciences, Qom, Iran.
E-mail addresses: h.maroofi@yahoo.com (H. Maroofi), kakhoundzadeh@muq.ac.ir (K. Akhoundzadeh), hasayesh@gmail.com (H. Asayesh).

https://doi.org/10.1016/j.heliyon.2024.e32615
Received 28 July 2023; Received in revised form 5 June 2024; Accepted 6 June 2024
Available online 17 June 2024

possible link between the COVID-19 pandemic and the incidence of out-of-hospital cardiac arrest (OHCA) [4]. OHCA is a global health problem and a time-critical, life-threatening emergency that occurs millions of times annually [5]. Data from countries around the world show a global average of 82.1 cases of EMS-treated OHCA per 100,000 people per year [6]. OHCA not only leads to a large disease burden but also results in social and economic costs in many communities [7]. The overall outcomes of OHCA vary considerably across regions, but are generally poor, and need to be improved [8].

The COVID-19 pandemic led to unprecedented challenges and impacts on health services worldwide, including EMS. This is especially true for medical emergencies such as OHCA [9]. Studies have shown that the characteristics of OHCA during the outbreak differ from those during the non-pandemic period, likely related to the direct or indirect impact of the COVID-19 pandemic [4,10–12]. Although there were fewer calls during the lockdown than expected, strangely, longer EMS response times and delays in treatment were reported [13]. Timely EMS response and advanced life support interventions, including airway management, medication administration, and defibrillation are key factors contributing to improved outcomes in OHCA. These factors are critical in the pre-hospital management of OHCA patients [14].

EMS in many countries was affected by the COVID-19 pandemic. A study from Singapore reported that at the beginning of the COVID-19 pandemic, all emergency medical service personnel were ordered to use personal protective equipment, including masks, goggles, and protective clothing for any cases that are deemed suspicious [15]. In another study, to reduce the duration of EMS missions, new ambulances were deployed to different locations [16]. Nevertheless, the EMS experienced a significant increase in workload, resulting in structural modifications and changes in guidelines and protocols [17].

Similar to numerous other countries, EMS in Iran was adversely affected by the COVID-19 pandemic. Currently, approximately 20,000 EMS personnel provide services in Iran's Emergency Organization at operational, communication, personnel and training levels. In the structure and composition of Iran's pre-hospital emergency system, two people in the role of EMS personnel and a doctor provide assistance through telephone calls and consultations. The Advanced Life Support (ALS) team including paramedics, or emergency nurse practitioners are qualified for conducting advanced cardiac life support and essential life-saving procedures such as advanced airway insertion, and CPR drug administration and followed American Heart Association Guidelines for Cardiopulmonary Resuscitation [18].

OHCA in the COVID-19 pandemic caused many challenges for emergency medical personnel [19]. One of the challenges was exposure to COVID-19 infection during the management of cardiac arrest, which inevitably prolonged scene time and probably compromised the quality of resuscitation [20]. Researchers have surmised that the lower rate of successful resuscitation in OHCA during the COVID-19 pandemic is due to the higher severity of the disease and the work overload in emergency medical services [21]. The likelihood of survival after OHCA can be significantly increased if immediate emergency measures for cardiopulmonary resuscitation are initiated [5]. Overall, according to current studies, COVID-19 affected OHCA and its management in many countries. Because of differences between countries in COVID-19 related aspects such as incidence and mortality rates, control strategies, and government approaches [22], studies in different countries seem to be essential to provide more valid and real evidence on COVID-19. These comprehensive data can also help deal with other viruses that may spread quickly and cause an epidemic. We should learn lessons from the COVID-19 disease to prevent future infectious diseases. This study investigated the impact of the COVID-19 pandemic on significant aspects related to the pre-hospital management of out-of-hospital cardiac arrest such as response times, interventions, and outcomes.

2. Methods

2.1. Study design

This descriptive-analytical study was performed on adult OHCA patients attended by EMS providers in Qom City, Iran. The checklist for reporting of observational studies by the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guidelines (https://www.strobe-statement.org/checklists/) was used to conduct the study and report the findings. The present study compared the OHCA cases during the waves of the COVID-19 pandemic to those during the pre-COVID-19 period. This study was approved by the Research Ethics Committees of Qom University of Medical Sciences (IR.MUQ.REC.1401.102). All methods were performed in accordance with the relevant legislation and guidelines of the National Committee for Ethics in Biomedical Research of Iran's Ministry of Health and Medical Education (https://ethics.research.ac.ir).

2.2. Study setting

The study was conducted in Qom City, Iran, with a population of 1.2 million people spread over almost 11,238 km^2 [23]. The study setting was the EMS center in Qom. The Qom EMS center has a registration system and the information of patients, from the moment the client calls the dispatch center until ending the related mission, whether transported to a hospital or not, is recorded routinely. EMS providers receive additional pre-hospital critical care training for the most life-threatening cases including OHCA. During the pandemic, the Qom EMS followed the infection prevention and control guidance published by the Ministry of Health and Medical Education, requiring personnel to wear personal protective equipment, including disposable gloves, surgical/N95 mask, gown, and eye protection during contact with patients.

2.3. Data sources

Data were collected from the Qom EMS center registration system, including electronic records (Asayar smart program) and paper reports of pre-hospital emergency operations at emergency medical services in Qom. Data were gathered from medical records of OHCA patients during the first 3 waves of the COVID-19 pandemic (from February 20, 2020 to June 22, 2021) and corresponding times of the pre-COVID-19 pandemic (from February 20, 2018 to June 22, 2019). The data from 1260 OHCA patients collected based on a census method were included in the study. Informed consent was waived due to the nature of the study. The registry was based on the Utstein template guidelines for reporting OHCA [24]. The steps for variable selection are as follows: Variables related to baseline characteristics (including age, gender, underlying disease, etiology of arrest, OHCA location, and EMS call time), EMS interventions (chest compressions, endotracheal intubation, epinephrine administration, and defibrillation), EMS times (triage time, reaction time, response time, hospital arrival time, duration of resuscitation), and patient outcomes were examined. Triage time was defined as the duration from sending patient information to the dispatch and coordination center to the moment of sending a message to the EMS station. Reaction time was defined as the duration of the mission announcement to the EMS station until ambulance departure. Response time is the time interval from the call to the ambulance's arrival at the scene. Hospital arrival time was defined as the time interval from leaving the scene to reaching the hospital. The Inclusion criteria were the occurrence of out-of-hospital cardiac arrest in non-traumatic people over 18 years of age who received out-of-hospital cardiopulmonary resuscitation by pre-hospital emergency medical personnel after telephone triage by dispatch experts. Exclusion criteria included the death of the patient at the scene before the ambulance arrived and patients whose information was incompletely recorded in the pre-hospital emergency operations registration system (Table 6). Eligible patients were assigned to the pre-COVID-19 period group and the COVID-19 period group. Since data were gathered from medical records and documents, there were no significant missing data.

2.4. Statistical analysis

A descriptive analysis was performed to examine the distribution of variables. Continuous variables are presented as the mean and standard deviation (SD), and categorical variables are presented as frequencies and proportions. Differences between groups were calculated for continuous variables using an independent *t*-test and for categorical variables using a chi-square test or Fisher's exact test, as appropriate. Multivariate logistic regression was used to estimate the adjusted odds ratio (aOR) for the effect of the COVID-19 pandemic on pre-hospital ROSC, accounting for patient and event characteristics. To select variables in logistic regression, prior empirical studies, clinical considerations, univariate statistical analyses, and potential confounding variables were considered. The adjusted factors were COVID-19, age, underlying disease, reaction time, response time, resuscitation time, hospital arrival time,

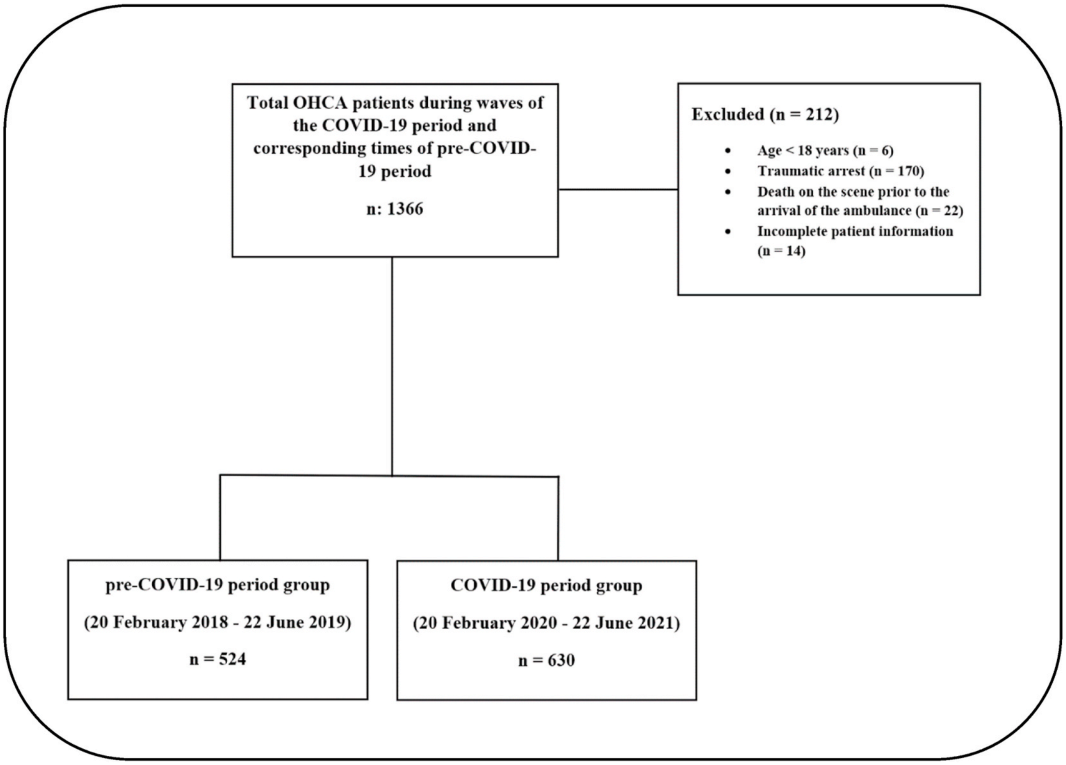

Fig. 1. STROBE flow chart.

endotracheal intubation, defibrillation, and epinephrine. All tests were two-sided, and a P-value <0.05 was considered statistically significant. The statistical software SPSS version 26.0 was used for all analyses.

3. Results

The data flow diagram of the study is illustrated in Fig. 1. From 1366 OHCA patients registered during waves of the COVID-19 period from February 20, 2020 to June 22, 2021 and corresponding times of the pre-COVID-19 period from February 20, 2018 to June 22, 2019, 212 patients were excluded from the study. Ultimately, the study analyzed the data of 1154 patients: 524 (45.4 %) from the pre-COVID-19 period group and 630 (54.6 %) from the COVID-19 period group. The incidence of OHCA increased during the pandemic period (Fig. 1).

Table 1 details the baseline characteristics of out-of-hospital cardiac arrest patients during the COVID-19 period and before the COVID-19 period in this study. The results showed OHCA patients were older during the pre-COVID-19 period than those during COVID-19 (mean age 64 vs. 62.1; $p = 0.009$). Between the two groups, there were no significant differences in gender. There were no statistically significant differences between the two groups in terms of underlying disease. In this study, an increase in the number of cardiac arrests at home (75.6 % vs. 93.2 %; $p < 0.001$) and a decrease in the number of cardiac arrests in public places were observed during the COVID-19 period (6.1 % vs. 1.9 %; $p < 0.001$). There were no statistically significant differences between the two groups in terms of EMS call time. The results showed that cardiac arrests of a medical etiology in the pre-COVID-19 period group were fewer compared with those in the COVID-19 period group (94.5 % vs. 98.7 %; $p = 0.007$).

Table 2 shows the detailed time difference in the pre-hospital course between the pre-COVID-19 period group and the COVID-19 period group. Reaction time and response time were longer during COVID-19 (96 s vs. 74.5 s, $p < 0.001$; and 9.1 min vs. 7.6 min, $p < 0.001$ respectively). Triage time, hospital arrival time, and duration of resuscitation were all longer during pre-COVID-19 (52.1s vs. 50.9 s, $p = 0.034$; 6.8 min vs. 6 min, $p < 0.001$; and 29.1 min vs. 22.7 min, $p < 0.001$ respectively).

The results of the comparison between groups in terms of the pre-hospital interventions are presented in Table 3. There was a significant decrease in pre-hospital endotracheal intubation (50.2 % vs. 17 %; $P < 0.001$) and defibrillation (40.1 % vs. 22.5 %; $P < 0.001$) during the COVID-19 outbreak. There was no significant difference in the percentage of patients who received epinephrine (39.4 % vs. 61.3 %, $p = 0.85$). Chest compression by EMS was also similar in both groups.

Table 4 shows the hospital outcomes of the pre-COVID-19 and COVID-19 period groups. The percentage of cases that achieved pre-hospital ROSC was lower during the COVID-19 period than during the pre-COVID-19 period (8.4 % vs. 15.6 %, $P < 0.001$).

The results of regression analysis done to investigate associations between the COVID-19 pandemic and pre-hospital ROSC are shown in Table 5. According to univariate analysis, ROSC was predicted by COVID-19, age, underlying disease, reaction time, response time, resuscitation time, hospital arrival time, endotracheal intubation, defibrillation, and epinephrine. After multivariate analysis, COVID-19 was not a statistically significant independent predictor anymore. The predictive power of the model was evaluated using a Nagelkerke R Square (0.47) and Cox and Snell R^2 (0.24). The Hosmer-Lemeshow goodness of fit test showed that the model is a good fit of the data ($p = 0.88$). Also, overall percentage correct of the multivariate logistic regressions was % 89.7.

Table 1
Baseline characteristics of patients with out-of-hospital cardiac arrest in the COVID-19 and pre-COVID-19 periods.

Variable	Pre-COVID-19 period N = 524	COVID-19 period N = 630	P value
Age (Mean ± SD)	64 ± 11.8	62.1 ± 11.6	0.009
Gender (male) n (%)	291 (55.5)	370 (58.7)	0.282
Underlying disease n (%)			0.05
Cardiac disease	375 (71.6)	418 (66.3)	
Respiratory disease	51 (9.7)	55 (8.7)	
Cardiac and Respiratory Disease	44 (8.4)	74 (11.7)	
Others	20 (3.8)	52 (8.3)	
Not reported	34 (6.5)	31 (4.9)	
Etiology of arrest n (%)			0.007
Medical	495 (94.5)	616 (98.7)	
Overdose/poisoning	20 (3.8)	12 (1.9)	
Drowning/Asphyxia	9 (1.7)	2 (0.3)	
OHCA location n (%)			<0.001
Home	396 (75.6)	578 (93.2)	
Street/Highway	56 (10.7)	18 (2.9)	
Workplace	40 (7.6)	13 (2.1)	
Public building	32 (6.1)	12 (1.9)	
EMS call time (24 h) n (%)			0.2
0-6	61 (11.6)	87 (13.8)	
6-12	149 (28.4)	173 (27.5)	
12-18	171 (32.6)	227 [36]	
18-24	143 (27.3)	143 (22.7)	

Table 2
Comparison of EMS times between the COVID-19 and pre-COVID-19 periods in OHCA patients.

Variable	Groups	Mean (SD)	P value
Triage Time, sec	Pre-COVID-19 period	52.1 (10/49)	0.034
	COVID-19 period	50.9 (8/79)	
Reaction Time, sec	Pre-COVID-19 period	74.5 (16/3)	<0.001
	COVID-19 period	96 (16/36)	
Response Time, min	Pre-COVID-19 period	7.6 (1/49)	<0.001
	COVID-19 period	9.1 (3/9)	
Hospital arrival time, min	Pre-COVID-19 period	6.8 (1/54)	<0.001
	COVID-19 period	6 (1/27)	
Duration of Resuscitation, min	Pre-COVID-19 period	29.1 (3/78)	<0.001
	COVID-19 period	22.7 (3/69)	

Table 3
Comparison of EMS interventions between the COVID-19 and pre-COVID-19 periods in OHCA patients.

Variable	Groups	n (%)	P value
Endotracheal intubation	Pre-COVID-19 period	263 (50.2)	<0.001
	COVID-19 period	107 [17]	
Chest compressions by EMS	Pre-COVID-19 period	524 (100)	–
	COVID-19 period	630 (100)	
Defibrillation	Pre-COVID-19 period	210 (40.1)	<0.001
	COVID-19 period	142 (22.5)	
Epinephrine administered	Pre-COVID-19 period	328 (60.6)	0.85
	COVID-19 period	248 (39.4)	

Table 4
Outcomes of patients with OHCA resuscitations in the COVID-19 and pre-COVID-19 periods.

Variable	Pre-COVID-19 period	COVID-19 period	P value
Outcome %			<0.001
Death in the field	409 (78.1)	553 (87.8)	
Transported with ongoing CPR	33 (6.3)	24 (3.8)	
Transported with ROSC	82 (15.6)	53 (8.4)	

4. Discussion

COVID-19 affected the performance of the emergency medical service (EMS) system in pre-hospital care, including the management of out-of-hospital cardiac arrests. This study investigated the impact of the COVID-19 pandemic on pre-hospital management of OHCAs and its outcomes in Qom City, Iran.

According to the results of the present study, during the COVID-19 period, non-traumatic out-of-hospital cardiac arrests increased by 20.2 %. EMS-related times differed between COVID-19 and non-COVID-19 period groups. The results of multivariate analysis showed that age, response time, hospital arrival time, endotracheal intubation, defibrillation, and epinephrine administration were predictors of ROSC.

Similar to our results, it was reported that out-of-hospital cardiac arrests increased in northern Italy during COVID-19 [25]. A threefold increase in non-traumatic cardiac arrests occurred in New York City during the COVID-19 pandemic [26]. According to the existing evidence, the increase in the OHCA incidence could be explained by the direct (e.g. respiratory failure and myocardial involvement caused by SARS-CoV-2) or indirect (such as the failure to activate emergency personnel in time-dependent cases) effects of COVID-19 [27–29]. It has been observed that patients during the COVID-19 period are less inclined to seek emergency medical care at hospitals, particularly when experiencing cardiac difficulties. This trend has been suggested as a possible explanation for the increase in out-of-hospital cardiac arrest [30].

The present study's findings showed that along with the increase in OHCA, the death rate also increased. In agreement with our finding, The mortality rate in London increased by 81 % from 19.2 % to 34.8 % during the COVID-19 pandemic [4]. The direct and indirect effects of COVID-19 could explain the increased incidence of death. Indirect impacts from lockdowns, delaying consultations, the adjustment of healthcare systems, and overburdening EMS are likely to be involved in mortality [27]. Also, the pandemic created a culture of fear. The fear of COVID-19 transmission may have diminished bystanders' motivation to engage in CPR during cardiac arrest.

The results reported that cardiac arrests occurred more frequently at home compared to public places during the COVID-19 period. An American study found a 76 % increase in cardiac arrests at home during the COVID-19 epidemic [31]. The increase in cardiac arrests at residences could be explained by the fact that patients were advised to stay home and avoid social contact to reduce the spread of COVID-19. In addition, with the beginning of the COVID-19 pandemic, many of these public places were closed. The high

Table 5
Univariate and multivariate analysis factors of prehospital ROSC during the COVID-19 period and before the COVID-19 period. The factors that were found to contribute to the prehospital ROSC in the univariate analysis at P values < 0.2 were included in the multivariate.

Variable	Univariate analysis			Multivariate analysis		
	Odd ratio	95%CI	P value	Odd ratio	95%CI	P value
COVID-19						
Non-COVID-19 period	[Reference]			[Reference]		
COVID-19 period	0.50	0.34–0.71	<0.001	0.85	0.40–1.82	0.68
Age	0.9	0.88–0.91	<0.001	0.91	0.89–0.93	<0.001
Gender				–	–	–
Female	[Reference]			[Reference]		
Male	0.80	0.56–1.16	0.24	–	–	–
Underlying disease						
Not reported	[Reference]			[Reference]		
Cardiac disease	0.143	0.82–0.25	<0.001	0.64	0.32–1.27	0.207
Respiratory Disease	0.25	0.12–0.52	<0.001	1.55	0.60–3.97	0.362
Respiratory and Cardiac disease	0.15	0.07–0.34	<0.001	0.57	0.22–1.48	0.252
Others	0.36	0.17–0.78	0.009	0.88	0.34–2.23	0.781
OHCA location				–	–	–
Public building	[Reference]			[Reference]		
Home	1.86	0.56–6.11	0.3	–	–	–
Street/Highway	1.65	0.41–6.6	0.47	–	–	–
Workplace	1.74	0.41–7.42	0.45	–	–	–
EMS call time	1	0.97–1.03	0.96	–	–	–
Triage Time	1	0.98–1.02	0.55	–	–	–
Reaction Time	0.98	0.97–0.99	0.006	0.10	0.98–1.01	0.66
Response Time	0.61	0.54–0.69	<0.001	0.73	0.63–0.86	<0.001
Resuscitation time	1.05	1.01–1.09	0.006	0.97	0.92–1.03	0.37
Hospital arrival time	0.71	0.61–0.83	<0.001	0.75	0.63–0.89	0.001
Endotracheal intubation						
No	[Reference]			[Reference]		
Yes	0.13	0.09–0.2	<0.001	0.32	0.2–0.53	<0.001
Defibrillation						
NO	[Reference]			[Reference]		
Yes	0.12	0.08–0.18	<0.001	0.32	0.2–0.5	<0.001
Epinephrine						
NO	[Reference]			[Reference]		
Yes	0.04	0.02–0.12	<0.001	0.1 2	0.04–0.31	<0.001

Table 6
Detailed table of variable selection.

Variable Category	Description
Baseline Characteristics	✓ Age ✓ Gender ✓ Underlying disease ✓ Etiology of arrest ✓ OHCA location ✓ EMS call time
EMS Interventions	✓ Endotracheal intubation ✓ Chest compressions by EMS ✓ Defibrillation ✓ Epinephrine administered
EMS Times	✓ Triage Time ✓ Reaction Time ✓ Response Time ✓ Hospital arrival time ✓ Duration of Resuscitation
Patient Outcomes	✓ Death in the field ✓ Transported with ongoing CPR ✓ Transported with ROSC
Exclusion Criteria	✓ Age < 18 years ✓ Traumatic arrest ✓ Death on the scene prior to the arrival of the ambulance ✓ Incomplete patient information

number of cardiac arrests that took place at home could be attributed to lockdown measures and health care system reorganization [10].

The increase in EMS process time during the COVID-19 period in this study is consistent with the findings of other studies. A Taiwanese study reported that the mean EMS response time and the interval from call to EMT departure for OHCA cases were longer in the COVID-19 period [32]. Similarly, a study conducted in the United States found that response times and scene times increased while transport times decreased [33]. It seems that taking additional information in the dispatch center regarding COVID-19 symptoms, history of travel to affected areas, and contacts with high-risk individuals led to a longer EMS response time. In addition, during the pandemic, the volume of incoming calls increased. As part of the COVID-19 pandemic preparations, EMS providers had to wear personal protective equipment, and this additional preparation could result in a longer EMS process time. Significant alterations in ambulance access and operations because of changes in EMS caseload, and restrictions on paramedics wearing personal protective equipment may have resulted in delays in outpatient therapy and impacted ambulance response times [34].

In spite of the reported reduction in road traffic during the pandemic, EMS call-to-arrival time increased during the epidemic. Although the decreased road traffic was expected to improve EMS call-to-arrival time, the delay resulting from taking time to put on personal protective equipment (PPE) and the shortages of ambulances and emergency medical service employees likely led to a longer time. It was reported that clinical concerns regarding the risk of transmission of COVID-19 and the time-consuming process of putting on PPE can negatively impact ambulance response time and lead to delays in patient treatment [34]. Besides being time-consuming, PPE is cumbersome and can affect healthcare delivery [35]. Also, various factors can contribute to the prolongation of response time, such as the timing of incidents, road conditions, weather conditions, the location of incidents, the occurrence of mass casualty incidents, as well as the increase in dispatcher workload due to an increase in emergency calls [36,37]. It is believed that the rise in COVID-19 patients needing transportation has led to a reduction in the availability of ambulances. This is because ambulance teams need to sanitize vehicles and equipment, as well as discard waste, after assisting and transporting COVID-19 patients, causing the vehicles to be marked as out-of-service. Consequently, this procedure has caused a decline in operational effectiveness, resulting in longer response times.

The COVID-19 outbreak resulted in a dramatic drop in endotracheal intubation, according to the study. In agreement with this finding, a study in a systematic review also found fewer intubations during the COVID-19 pandemic [38]. It seems that the alternative ways of maintaining the airway, particularly supraglottic devices recently widely used in some countries such as South Korea, Spain, and USA [31,39,40], could be an explanation for the reduction in endotracheal intubation. In this regard, the Iran National Medical Emergency Organization's clinical practice guidelines recommend supraglottic airway devices as an adjunct to endotracheal intubation [41]. Rapid transport without endotracheal intubation has also been recommended in some studies to reduce the risk of infection for rescuers and the number of rescuers involved in resuscitation [42]. Since intubation has been designated by the World Health Organization as an aerosol-generating procedure, EMS clinical practice guidelines were modified [43].

The present study revealed that defibrillation decreased during the COVID-19 outbreak. Similarly, a study conducted in the United States found that EMS-performed defibrillation was significantly lower following the stay-at-home order and may be associated with undiagnosed COVID-19 [44]. According to existing evidence, the complications of COVID-19 (including hypoxia, myocardial infarction, and thromboembolism) may cause cardiac arrest with an initially non-shockable rhythm [26,45]. Unlike defibrillation, there was no significant difference in Epinephrine administration between the two groups. This finding was in agreement with the report of a systematic review and meta-analysis and a study in Japan that showed epinephrine administration to OHCA patients did not differ between COVID-19 and non-COVID-19 periods [38,46].

There was a significant decrease in ROSCs in OHCA patients during the COVID-19 period, compared to that before COVID-19. During the COVID-19 period, pre-hospital ROSC numbers were low because of both the direct and indirect effects of COVID-19 on patients and healthcare systems. The decrease in ROSCs during the COVID-19 period was also reported in studies conducted in the United States, Italy, and Spain [21,47,48]. People with OHCA appear to have worse outcomes when infected with COVID-19 in the community [21]. Although ROSC rate was lower during the COVID-19 period, according to the results of multivariate analysis, COVID-19 was not a predictor factor of ROSCs. There are some studies that can partially support this result. A study in Detroit showed that the rate of pre-hospital ROSC did not change during COVID-19 despite the increase in OHCA [49]. Also, there was no significant difference in the ROSC rate between pre-COVID and COVID periods in Singapore [50]. Similarly, no apparent effect of the COVID-19 pandemic on pre-hospital ROSC was reported in Western Australia [51]. Another study in Australia showed that changes during the COVID-19 period did not impact survival outcomes in EMS-witnessed OHCA [52]. Although similar to many studies [9,53,54], our findings showed worse outcomes of OHCA in the COVID-19 period compared to the pre-COVID period, it seems some factors impact the association between COVID-19 and outcomes. One possible explanation for the findings of multivariate analysis that failed to demonstrate an association between ROSCs and COVID-19 could be attributed to disparities in age. Since the patients in the COVID-19 period were significantly younger than those in the pre-COVID-19 period, the success rate of CPR and ROSC may have been affected. Differences in EMS times and interventions between the COVID-19 and pre-COVID-19 periods may also have affected the result of the multivariate analysis of ROSC.

According to Nagelkerke R Square and Cox and Snell R^2 values, the model predicted the dependent variable between 24 and 47 %, therefore there are other variables outside the model that significantly influence OHCA outcomes during the pandemic. Some external pandemic-related factors that might have influenced the outcomes include hospital capacity, public health measures, EMS personnel experience, EMS equipment, and bystander intervention. Anyway, the etiologies of our results are likely multifactorial and need further investigation on the complex interplay of factors influencing the results.

Changes in EMS resuscitation guidelines for OHCA patients during the COVID-19 pandemic due to resource limitations, uncertainties early in the pandemic, and workforce shortages and resources could impact pre-hospital management, interventions, response times, and other related factors and consequently the outcomes.

4.1. Strengths and limitations of study

Numerous studies have already researched the effect of COVID-19 on OHCA management and outcome, however this study is one of the few studies released in Middle Asian countries. Research like the present study on the impact of critical situations such as the COVID-19 pandemic on OHCA managements is necessary to improve OHCA outcomes. The findings of such studies can be helpful for further preparedness for similar emergencies or other crises in the future. By understanding the involved factors, a better response can be developed in the future, and lives can be saved. The findings of the study with an acceptable sample size and an integrated EMS database that reported some important aspects of pre-hospital system performance in a pandemic crisis can be used as an information source for healthcare system managers to know the weaknesses and shortages of the system.

One of study' limitations was that the registry system did not record data on in-hospital treatment and outcomes. Due to the unavailability of this information, the survival rate and neurological outcomes at discharge could not be evaluated. Moreover, we had no data on confirmed COVID-19 infected cases in our study because the study was done during the first peaks of COVID-19 and a polymerase chain reaction (PCR) test was not carried out in OHCA patients at the beginning of COVID-19 outbreak. Therefore, we could not definitively prove that COVID-19 was the cause of deaths in out-of-hospital cardiac arrests. Time-related biases reported in nonrandomized COVID-19-era studies may have affected the results of the present study as confounding factors. Also, changes in public behaviors during the pandemic, which might influence EMS response times or OHCA occurrences can be considered as potential confounders.

Although there were no recall biases in the present study, the potential for information bias in EMS records might have existed, especially in the COVID-19 period whose extraordinary, unknown and life-threatening nature likely affected the health care system performance. Although data were gathered from medical records, and missing data was not a notable limitation, there was no assurance that information was recorded completely or accurately. Medical records, especially during high-stress periods like the COVID-19 pandemic, are prone to input errors.

Our results that represented a single city, Qom with individual socioeconomic, demographic, geographic, and healthcare system characteristics may not be generalizable to other cities or countries. Also, as a retrospective study, the results need to be treated with caution.

5. Conclusion

During COVID-19, OHCA rates increased while outcomes among cardiac arrest patients deteriorated. It also demonstrated significant changes in the pre-hospital responses that likely affected the outcomes of OHCA patients. Therefore, health authorities should seriously consider our results when planning healthcare strategies to deal with the pandemic, not neglecting the pre-hospital issue of the emergency, especially considering the expected recurrent outbreaks.

Ethical statements

This work approved by Iran National Committee for Ethics in Biomedical Research (record no. IR.MUQ.REC.1401.102) was supported by Qom University of Medical Science, Qom, Iran. Informed consent was waived due to the nature of the study. The article was extracted from the MSc. student thesis of Himan Maroofi.

Consent for publication

Not applicable.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

CRediT authorship contribution statement

Himan Maroofi: Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Kobra Akhoundzadeh:** Writing – review & editing, Supervision, Software, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Hamid Asayesh:** Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors would like to acknowledge the Qom EMS Department and all the providers that support pre-hospital care and serve on the Qom province's frontlines.

References

[1] P. Sun, X. Lu, C. Xu, W. Sun, B. Pan, Understanding of COVID-19 based on current evidence, J. Med. Virol. 92 (6) (2020) 548–551.
[2] H. Khankeh, M. Farrokhi, H.T. Ghadicolaei, S.A. Mazhin, J. Roudini, Y. Mohsenzadeh, Z. Hadinejad, Epidemiology and factors associated with COVID-19 outbreak-related deaths in patients admitted to medical centers of Mazandaran University of Medical Sciences, J. Educ. Health Promot. 10 (2021) 426.
[3] C. Wang, P.W. Horby, F.G. Hayden, G.F. Gao, A novel coronavirus outbreak of global health concern, Lancet 395 (10223) (2020) 470–473.
[4] R.T. Fothergill, A.L. Smith, F. Wrigley, G.D. Perkins, Out-of-Hospital cardiac arrest in London during the COVID-19 pandemic, Resusc Plus 5 (2021) 100066.
[5] S.C. Brooks, G.R. Clegg, J. Bray, C.D. Deakin, G.D. Perkins, M. Ringh, et al., Optimizing outcomes after out-of-hospital cardiac arrest with innovative approaches to public-access defibrillation: a scientific statement from the International Liaison Committee on Resuscitation, Resuscitation 172 (2022) 204–228.
[6] K. Dyson, S.P. Brown, S. May, K. Smith, R.W. Koster, S.G. Beesems, et al., International variation in survival after out-of-hospital cardiac arrest: a validation study of the Utstein template, Resuscitation 138 (2019) 168–181.
[7] E.D. Paratz, K. Smith, J. Ball, A. van Heusden, D. Zentner, S. Parsons, et al., The economic impact of sudden cardiac arrest, Resuscitation 163 (2021) 49–56.
[8] T. Kiguchi, M. Okubo, C. Nishiyama, I. Maconochie, M.E.H. Ong, K.B. Kern, et al., Out-of-hospital cardiac arrest across the world: first report from the international liaison committee on resuscitation (ILCOR), Resuscitation 152 (2020) 39–49.
[9] E. Baldi, C. Klersy, P. Chan, J. Elmer, J. Ball, C.R. Counts, et al., The impact of COVID-19 pandemic on out-of-hospital cardiac arrest: an individual patient data meta-analysis, Resuscitation 194 (2024) 110043.
[10] E. Baldi, G.M. Sechi, C. Mare, F. Canevari, A. Brancaglione, R. Primi, et al., COVID-19 kills at home: the close relationship between the epidemic and the increase of out-of-hospital cardiac arrests, Eur. Heart J. 41 (32) (2020) 3045–3054.
[11] T. Scquizzato, G. Landoni, A.M. Scandroglio, A. Franco, M.G. Calabrò, A. Paoli, et al., Outcomes of out-of-hospital cardiac arrest in patients with SARS-CoV-2 infection: a systematic review and meta-analysis, Eur. J. Emerg. Med. 28 (6) (2021) 423–431.
[12] E. Baldi, A. Auricchio, C. Klersy, R. Burkart, C. Benvenuti, C. Vanetta, J. Bärtschi, Out-of-hospital cardiac arrests and mortality in Swiss Cantons with high and low COVID-19 incidence: a nationwide analysis, Resusc Plus 6 (2021) 100105.
[13] E. Andrew, Z. Nehme, M. Stephenson, T. Walker, K. Smith, The impact of the COVID-19 pandemic on demand for emergency ambulances in victoria, Australia, Prehosp. Emerg. Care (2021) 1–7.
[14] M.E.H. Ong, G.D. Perkins, A. Cariou, Out-of-hospital cardiac arrest: prehospital management, Lancet 391 (10124) (2018) 980–988.
[15] Q.X. Ng, E.Z. Lee, J.A. Tay, S. Arulanandam, Impact of COVID-19 'circuit-breaker' measures on emergency medical services utilisation and out-of-hospital cardiac arrest outcomes in Singapore, Emerg. Med. Australasia (EMA) 33 (1) (2021) 149–151.
[16] G. Stirparo, G. Ristagno, L. Bellini, R. Bonora, A. Pagliosa, M. Migliari, et al., Changes to the major trauma pre-hospital emergency medical system network before and during the 2019 COVID-19 pandemic, J. Clin. Med. 11 (22) (2022).
[17] S. Perlini, F. Canevari, S. Cortesi, V. Sgromo, A. Brancaglione, E. Contri, et al., Emergency department and out-of-hospital emergency system (112-AREU 118) integrated response to coronavirus disease 2019 in a northern Italy centre, Intern Emerg Med 15 (5) (2020) 825–833.
[18] K. Miri, M. Sabbaghi, S.R. Mazlum, M. Namazinia, The trend of change in the role of pre-hospital emergency medical services in Iran's healthcare system: a situational analysis, BMC Emerg. Med. 23 (1) (2023) 99.
[19] M.J. Borkowska, J. Smereka, K. Safiejko, K. Nadolny, M. Maslanka, K.J. Filipiak, et al., Out-of-hospital cardiac arrest treated by emergency medical service teams during COVID-19 pandemic: a retrospective cohort study, Cardiol. J. 28 (1) (2021) 15–22.
[20] A.K. Sahu, S. Suresh, R. Mathew, P. Aggarwal, J. Nayer, Impact of personal protective equipment on the effectiveness of chest compression - a systematic review and meta-analysis, Am. J. Emerg. Med. 39 (2021) 190–196.
[21] P.S. Chan, S. Girotra, Y. Tang, R. Al-Araji, B.K. Nallamothu, B. McNally, Outcomes for out-of-hospital cardiac arrest in the United States during the coronavirus disease 2019 pandemic, JAMA cardiology 6 (3) (2021) 296–303.
[22] N. Pearce, D.A. Lawlor, E.B. Brickley, Comparisons between Countries Are Essential for the Control of COVID-19, Oxford University Press, 2020, pp. 1059–1062.
[23] Statistics Qom, Statistical geographic information service: statistical Centre of Iran. https://www.amar.org.ir/Portals/0/census/1395/results/tables/jamiat/tafsili/ostani/9-jamiat-ostani.xls, 2016. (Accessed 13 March 2017).
[24] G.D. Perkins, I.G. Jacobs, V.M. Nadkarni, R.A. Berg, F. Bhanji, D. Biarent, et al., Cardiac arrest and cardiopulmonary resuscitation outcome reports: update of the Utstein resuscitation registry templates for out-of-hospital cardiac arrest: a statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart association, European resuscitation council, Australian and New Zealand council on resuscitation, Heart and stroke foundation of Canada, InterAmerican Heart foundation, resuscitation council of southern africa, resuscitation council of Asia); and the American Heart association emergency cardiovascular care committee and the council on cardiopulmonary, critical care, perioperative and resuscitation, Circulation 132 (13) (2015) 1286–1300.
[25] E. Baldi, G.M. Sechi, C. Mare, F. Canevari, A. Brancaglione, R. Primi, et al., Out-of-Hospital cardiac arrest during the covid-19 outbreak in Italy, N. Engl. J. Med. 383 (5) (2020) 496–498.
[26] P.H. Lai, E.A. Lancet, M.D. Weiden, M.P. Webber, R. Zeig-Owens, C.B. Hall, D.J. Prezant, Characteristics associated with out-of-hospital cardiac arrests and resuscitations during the novel coronavirus disease 2019 pandemic in New York city, JAMA cardiology 5 (10) (2020) 1154–1163.
[27] E. Marijon, N. Karam, D. Jost, D. Perrot, B. Frattini, C. Derkenne, et al., Out-of-hospital cardiac arrest during the COVID-19 pandemic in Paris, France: a population-based, observational study, Lancet Public Health 5 (8) (2020) e437–e443.
[28] T. Scquizzato, F. D'Amico, M. Rocchi, M. Saracino, F. Stella, G. Landoni, A. Zangrillo, Impact of COVID-19 pandemic on out-of-hospital cardiac arrest system-of-care: a systematic review and meta-analysis, Prehosp. Emerg. Care (2021) 1–12.
[29] K.J. Clerkin, J.A. Fried, J. Raikhelkar, G. Sayer, J.M. Griffin, A. Masoumi, et al., COVID-19 and cardiovascular disease, Circulation 141 (20) (2020) 1648–1655.
[30] A.A. Husain, U. Rai, A.K. Sarkar, V. Chandrasekhar, M.F. Hashmi, Out-of-Hospital cardiac arrest during the COVID-19 pandemic: a systematic review, Healthcare (Basel) 11 (2) (2023).
[31] D. Lim, S.Y. Park, B. Choi, S.H. Kim, J.H. Ryu, Y.H. Kim, et al., The comparison of emergency medical service responses to and outcomes of out-of-hospital cardiac arrest before and during the COVID-19 pandemic in an area of Korea, J. Kor. Med. Sci. 36 (36) (2021) e255.
[32] J.H. Yu, C.Y. Liu, W.K. Chen, S.H. Yu, F.W. Huang, M.T. Yang, et al., Impact of the COVID-19 pandemic on emergency medical service response to out-of-hospital cardiac arrests in Taiwan: a retrospective observational study, Emerg. Med. J. 38 (9) (2021) 679–684.
[33] T. Satty, S. Ramgopal, J. Elmer, V.N. Mosesso, C. Martin-Gill, EMS responses and non-transports during the COVID-19 pandemic, Am. J. Emerg. Med. 42 (2021) 1–8.
[34] M.D. Christian, K. Couper, COVID-19 and the global OHCA crisis: an urgent need for system level solutions, Resuscitation 157 (2020) 274–276.

[35] J. Kang, J.M. O'Donnell, B. Colaianne, N. Bircher, D. Ren, K.J. Smith, Use of personal protective equipment among health care personnel: results of clinical observations and simulations, Am. J. Infect. Control 45 (1) (2017) 17–23.
[36] J.L. Heemskerk, K.O. Abode-Iyamah, A. Quinones-Hinojosa, E.S. Weinstein, Prehospital response time of the emergency medical service during mass casualty incidents and the effect of triage: a retrospective study, Disaster Med. Public Health Prep. 16 (3) (2022) 1091–1098.
[37] T. Scquizzato, G. Landoni, A. Paoli, R. Lembo, E. Fominskiy, A. Kuzovlev, et al., Effects of COVID-19 pandemic on out-of-hospital cardiac arrests: a systematic review, Resuscitation 157 (2020) 241–247.
[38] Y. Masuda, S.E. Teoh, J.W. Yeo, D.J.H. Tan, D.L. Jimian, S.L. Lim, et al., Variation in community and ambulance care processes for out-of-hospital cardiac arrest during the COVID-19 pandemic: a systematic review and meta-analysis, Sci. Rep. 12 (1) (2022) 800.
[39] F. Rosell Ortiz, P. Fernández Del Valle, E.C. Knox, X. Jiménez Fábrega, J.M. Navalpotro Pascual, I. Mateo Rodríguez, et al., Influence of the Covid-19 pandemic on out-of-hospital cardiac arrest. A Spanish nationwide prospective cohort study, Resuscitation 157 (2020) 230–240.
[40] N.K. Glober, M. Supples, G. Faris, T. Arkins, S. Christopher, T. Fulks, et al., Out-of-hospital cardiac arrest volumes and characteristics during the COVID-19 pandemic, Am. J. Emerg. Med. 48 (2021) 191–197.
[41] National Medical Emergency Organization, Prehospital Emergency Operating Processes, 2021 [Available from: https://ems.behdasht.gov.ir/. (Accessed 22 June 2021).
[42] S. Riyapan, J. Chantanakomes, P. Roongsaenthong, P. Tianwibool, B. Wittayachamnankul, J. Supasaovapak, W. Pansiritanachot, Impact of the COVID-19 outbreak on out-of-hospital cardiac arrest management and outcomes in a low-resource emergency medical service system: a perspective from Thailand, Int. J. Emerg. Med. 15 (1) (2022) 26.
[43] Infection prevention and control during health care when coronavirus disease (COVID-19) is suspected or confirmed 2021. https://www.who.int/publications/i/item/WHO-2019-nCoV-IPC-2021.1. (Accessed 12 July 2021).
[44] J.E. Rollman, R.A. Kloner, N. Bosson, J.T. Niemann, M. Gausche-Hill, M. Williams, et al., Emergency medical services responses to out-of-hospital cardiac arrest and suspected ST-segment-elevation myocardial infarction during the COVID-19 pandemic in Los Angeles county, J. Am. Heart Assoc. 10 (12) (2021) e019635.
[45] F. Ciceri, L. Beretta, A.M. Scandroglio, S. Colombo, G. Landoni, A. Ruggeri, et al., Microvascular COVID-19 lung vessels obstructive thromboinflammatory syndrome (MicroCLOTS): an atypical acute respiratory distress syndrome working hypothesis, Crit Care Resusc 22 (2) (2020) 95–97.
[46] C. Nishiyama, K. Kiyohara, T. Kitamura, S. Hayashida, T. Maeda, T. Kiguchi, et al., Impact of the COVID-19 pandemic on prehospital intervention and survival of patients with out-of-hospital cardiac arrest in osaka city, Japan, Circ. J. (2022).
[47] Z.J. Lim, M. Ponnapa Reddy, A. Afroz, B. Billah, K. Shekar, A. Subramaniam, Incidence and outcome of out-of-hospital cardiac arrests in the COVID-19 era: a systematic review and meta-analysis, Resuscitation 157 (2020) 248–258.
[48] K. Bielski, A. Szarpak, M.J. Jaguszewski, T. Kopiec, J. Smereka, A. Gasecka, et al., The influence of COVID-19 on out-hospital cardiac arrest survival outcomes: an updated systematic review and meta-analysis, J. Clin. Med. 10 (23) (2021).
[49] S. Mathew, N. Harrison, A.D. Chalek, D. Gorelick, E. Brennan, S. Wise, et al., Effects of the COVID-19 pandemic on out-of-hospital cardiac arrest care in Detroit, Am. J. Emerg. Med. 46 (2021) 90–96.
[50] Q.X. Ng, E.Z. Lee, J.A. Tay, S. Arulanandam, Impact of covid-19 'circuit-breaker'measures on Emergency Medical Services Utilisation and out-of-hospital cardiac arrest outcomes in Singapore, Emerg. Med. Australasia (EMA) 33 (1) (2021) 149–151.
[51] M. Talikowska, S. Ball, H. Tohira, P. Bailey, D. Rose, D. Brink, et al., No apparent effect of the COVID-19 pandemic on out-of-hospital cardiac arrest incidence and outcome in Western Australia, Resuscitation 8 (2021) 100183.
[52] C. Kennedy, Z. Alqudah, D. Stub, D. Anderson, Z. Nehme, The effect of the COVID-19 pandemic on the incidence and survival outcomes of EMS-witnessed out-of-hospital cardiac arrest, Resuscitation 187 (2023) 109770.
[53] K.Y. Leung, C.M.M. Chu, C.T. Lui, Exposure-response relationship between COVID-19 incidence rate and incidence and survival of out-of-hospital cardiac arrest (OHCA), Resuscitation 14 (2023) 100372.
[54] M. Dabkowski, D. Swieczkowski, M. Pruc, B. Cander, M. Gül, N. Bragazzi, L. Szarpak, Unraveling the consequences of the COVID-19 pandemic on out-of-hospital cardiac arrest: a systematic review and meta-analysis, Eurasian Journal of Emergency Medicine 22 (3) (2023).