

Comparison between automated cardiopulmonary resuscitation and manual cardiopulmonary resuscitation in the rescue of cardiac and respiratory arrest

Mengying Gao¹,
Huiping Niu², Shuang Yuan³

ABSTRACT

Objective: To compare the efficacy of automated cardiopulmonary resuscitation (A-CPR) and manual cardiopulmonary resuscitation (M-CPR) in the rescue of cardiac and respiratory arrest.

Methods: A retrospective, single-center observational study was conducted to identify 106 patients by reviewing medical records of 269 patients with cardiac and respiratory arrest treated in The Second Hospital of Hebei Medical University, Shandong Provincial Third Hospital (Jinan, China) from February 2019 to February 2021. Patients were divided into A-CPR group (n = 55) and M-CPR group (n = 51) based on the resuscitation treatment method. The groups were matched for age, gender and the cause of cardiac arrest. Rescue effects, blood gas analysis indicators, respiratory dynamics and condition improvement of the two groups were compared.

Results: In terms of rescue effects, return of spontaneous circulation (ROSC) rate, successful rate of cardiopulmonary resuscitation (CPR), 24-hour survival rate and survival discharge rate in the A-CPR group were higher than M-CPR group ($P < 0.05$). With respect to blood gas analysis indicators and respiratory dynamics, the partial pressure of carbon dioxide (PaCO_2) in the A-CPR group was lower than M-CPR group at 15 and 30 minutes after CPR, while the partial pressure of oxygen (PaO_2), blood oxygen saturation (SaO_2), end expiratory carbon dioxide (PetCO_2), coronary perfusion pressure (CPP) and mean arterial pressure (MAP) in the A-CPR group were higher than M-CPR group ($P < 0.05$). In aspect of condition improvement, spontaneous breathing, heart rate, spontaneous circulation, blood pressure recovery time and CPR time in the A-CPR group were shorter than M-CPR group ($P < 0.05$).

Conclusion: The application effect of A-CPR in the rescue of cardiac and respiratory arrest, the improvement of blood gas analysis indexes, respiration and condition improvement are more significant than M-CPR.

KEYWORDS: Automated cardiopulmonary resuscitation; Manual cardiopulmonary resuscitation; Cardiac and respiratory arrest; Blood gas analysis index; Respiratory dynamics.

doi: <https://doi.org/10.12669/pjms.38.8.6598>

How to cite this:

Gao M, Niu H, Yuan S. Comparison between automated cardiopulmonary resuscitation and manual cardiopulmonary resuscitation in the rescue of cardiac and respiratory arrest. *Pak J Med Sci.* 2022;38(8):2208-2214. doi: <https://doi.org/10.12669/pjms.38.8.6598>

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Correspondence:

Shuang Yuan,
Department of Intensive Care Unit,
Shandong Provincial Third Hospital,
Cheeloo College of Medicine,
Shandong University, 11 Wuyingshan Middle Road,
Jinan, Shandong Province 250031,
P.R. China.
Email: ooshuangerls@126.com

- * Pre-Submission Received: April 15, 2022
- * Received for Publication: May 8, 2022
- * Revision Received: September 3, 2022
- * Revision Accepted: September 6, 2022

INTRODUCTION

Cardiac arrest (CA) is a leading cause of mortality and morbidity globally. It is reported that there are more than 347000 and 7000 emergency medical services (EMS) responses to out-of-hospital cardiac arrest (OHCA) cases in the United States annually in adults and children, respectively.¹ The incidence of in-hospital cardiac arrest (IHCA) is reported to be 9.7 per 1000 adult cardiac arrests and 2.7 pediatric events

per 1000 hospitalizations.² Prompt provision of cardiopulmonary resuscitation (CPR) is one of the priorities of adult cardiac arrest management.³ CPR involves clearing patient's respiratory tract in combination with artificial respiration and chest compressions, and then carrying out professional drug intervention to establish artificial circulation and promote the recovery of cardiac function.⁴

Manual CPR (M-CPR) is the main CPR method, achieves CPR by manual external chest compression (cardiac pump and chest pump).⁵ However, the main disadvantages of manual external chest compression include limited auxiliary ventilation effect, insufficient compression frequency and depth and easy fatigue of the treating personnel. Interruptions during the compression may lead to cessation of blood supply to cerebral artery and coronary artery. In addition, manual external chest compression may cause rib and sternum fractures and directly affect the efficiency of CPR.^{6,7}

In recent years, automated CPR (A-CPR) are designed to improve chest compression quality, are gradually replacing manual external chest compression. A-CPR allows adjustment of depth, frequency and proportion of external chest compression according to the specific situation of the patient, and provides constant and lasting ventilation support and external chest compression.⁸

Over the past years, numbers of studies have investigated the effectiveness of A-CPR and M-CPR in OHCA patients^{9,10,11}, but few in IHCA patients. Therefore, we performed an observational study to analyze the efficacy of A-CPR and M-CPR in the rescue of cardiac and respiratory arrest by comparing their rescue effect, blood gas analysis index and respiratory dynamics, and condition improvement. Our hypothesis of this study was that the application of A-CPR would bring better outcomes than M-CPR in in-hospital patients.

METHODS

We conducted a retrospective, single-center observational study to identify 106 patients by reviewing medical records of 269 patients with cardiac and respiratory arrest who were resuscitated in The Second Hospital of Hebei Medical University, Shandong Provincial Third Hospital (Jinan, China) from February 2019 to February 2021. All the patients in the study underwent carotid artery examination. After cardiac and respiratory arrest was determined, venous access was timely established, ventilator-assisted ventilation and

endotracheal intubation were performed, and adrenaline was administered repeatedly every five minutes to strengthen ECG monitoring. Patients were divided into A-CPR group (n = 55) and M-CPR group (n = 51) based on the resuscitation treatment method they received. The groups were matched for age, gender and cause of arrest (Fig.1). This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.¹²

M-CPR group was performed adhering to the 2015 American Heart Association guidelines for CPR and cardiovascular first aid.¹³ Briefly, 5cm of sternal depression was located and compressions were administered at a speed of more than 100 times/minutes by 2~4 medical workers, five cycles/person, artificial respiration was performed, if the patient's spontaneous circulation has not recovered within 30 minutes after the last spontaneous cardiac arrest, or the patient's spontaneous circulation has successfully recovered, the rescue can be terminated.

Patients in the A-CPR group were resuscitated using SCC TM100 A-CPR (Sunlife company), connected to the air source, and the parameters were set to 30:2, resuscitation was stopped after the patient's autonomic circulation function recovered or after 120 minutes of CPR, if the autonomic circulation function failed to recover after 120 minutes, the rescue was terminated.

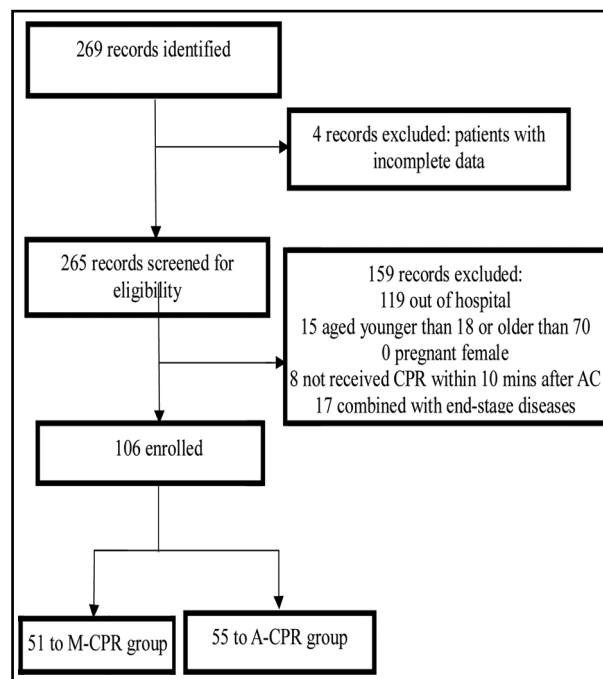


Fig.1: Flowchart of patient screening.

Inclusion criteria:

- Cardiac and respiratory arrest diagnosis,¹⁴ which was confirmed by electrocardiogram (ECG);
- Age ranges from 18 to 70 years;
- Patients received CPR within 10 mins after CA
- Patients with complete basic medical records

Exclusion criteria:

- Death before admission;
- Pregnant women;
- Combined with end-stage diseases such as aneurysm rupture or intracerebral hemorrhage;
- Complicated with severe organ dysfunction;
- Mental disorders;
- Cardiogenic shock, heart rupture, pump failure or ventricular septal perforation before cardiac and respiratory arrest.

Ethics Approval: This study protocol has been approved by the hospital ethics committee (Approval number: 2022-P012, Date: 2022-03-10).

Efficacy evaluation indicators: Rescue effect. Briefly, return of spontaneous circulation (ROSC), successful rate of CPR, 24-hour survival rate and survival discharge rate were statistically analyzed. The recovery standard of autonomic circulation is that the pulsing of great arteries is detectable, the effective heart rates (ventricular autonomic heart rate, sinus heart rate and borderline heart rate) can be detected by ECG, the systolic blood pressure exceeds 60mmHg and lasts for three minute or more.¹⁵ Successful CPR was defined as ROSC maintained for more than 30 minutes.¹⁶

Blood gas analysis index and respiratory dynamics: The indexes of blood gas analysis and respiratory dynamics were measured at five, 15 and 30 minutes after CPR, patient's venous blood samples were taken, and the oxygen partial pressure (PaO₂), carbon dioxide partial pressure (PaCO₂) and

blood oxygen saturation (SaO₂) were measured by Hitachi 7600 automatic biochemical analyzer. The end expiratory carbon dioxide partial pressure (PetCO₂), coronary perfusion pressure (CPP) and mean arterial pressure (MAP) were monitored by HP 8000LED multifunctional tester.

Condition improvement. The patients' spontaneous breathing, heart rate, spontaneous circulation, blood pressure recovery time and CPR time were recorded.

Outcomes The primary outcomes were ROSC rate and successful rate of CPR, which reflect the quality of CPR directly. The secondary outcomes included 24 hour survival rate and survival discharge rate, which may be affected by post-resuscitation care. It also included blood gas analysis indexes (PaO₂, PaCO₂ and SaO₂) and respiratory dynamics indicators (PetCO₂, CPP and MAP), and condition improvement indicators (spontaneous breathing, heart rate, spontaneous circulation, blood pressure recovery time and CPR time).

Statistical analysis: As per the previous study,¹⁷ the ROSC rate of A-CPR and M-CPR were 83% and 48.8%, respectively. Based on two-tailed test and assuming power set at 0.9, and variable missing as 10%, at least 40 cases would be needed for the study¹⁸. SPSS 22.0 (SPSS Inc., Chicago, IL, USA) was used for data processing. Descriptive statistics were used to describe the baseline information of the patients. Continuous variables were tested for normality by Shapiro-Wilk test. Normal distributions were described as mean standard deviation and groups were compared by t-test while abnormal distributions were compared by Mann-Whitney U test. Categorical variables are described as percentage or rate and were compared by the χ^2 test. For the primary outcomes, adjusted odds ratios (AORs) were also calculated by multivariate

Table-I: Comparison of baseline characteristics between the two groups

Characteristics	M-CPR group (n = 51)	A-CPR group (n = 55)	χ^2/t	P
Age (mean [SD], y)	52.53±8.40	50.14±7.99	1.497	0.137
Gender (male/female)	28/23	35/20	0.837	0.360
Cause of arrest (n, %)				
Poisoning	8 (15.69)	10 (18.18)		
Coronary Heart Disease	22 (43.14)	30 (54.54)	2.630	0.452
Cerebrovascular Disease	12 (23.53)	10 (18.18)		
Other	9 (17.65)	5 (9.09)		

logistic regression analysis with manual CPR as the reference group and controlling for the confounders (age, gender and cause of arrest). AORs were given with their 95% confidence interval (CI) and two-sided P values are presented. For the secondary outcomes, the groups were compared by the Mann-Whitney U test. $P < 0.05$ indicated that the difference was statistically significant. $P < 0.05$ indicated that the difference was statistically significant.

RESULTS

A total of 106 patients met the inclusion criteria, including 51 in the M-CPR group and 55 in the A-CPR group. As summarized in Table-I, there were 28 males and 23 females in the M-CPR group; with the age ranging from 37 to 69 years, an average of (52.53±8.40) years; among the patients, there were eight cases of poisoning, 22 cases of coronary heart disease, 12 cases of cerebrovascular disease and nine cases of other causes of cardiac and respiratory arrest. The A-CPR group included 35 males and 20 females; the age ranged from 35 to 69 years; with an average of (50.14±7.98) years; of 35 patients, there were 10 cases of poisoning, 30 cases of coronary heart disease, 10 cases of cerebrovascular disease and five cases of other causes of cardiac and respiratory arrest. There was no significant difference in general data between the two groups ($P > 0.05$), as shown in Table-I.

In terms of rescue effect, the ROSC rate [AOR = 3.61 (1.53, 8.54)], successful CPR rate [AOR = 3.11 (1.29, 7.51)], 24h survival rate [AOR = 3.65 (1.39, 9.61)] and survival discharge rate [AOR = 3.35 (1.17, 9.56)] of A-CPR group were more time three times higher than the A-CPR, and these findings were statistically significant ($p < 0.05$), as shown in Table-II.

In terms of blood gas analysis indexes and respiratory dynamics, there was no significant difference in PaCO₂, PaO₂, SaO₂, PetCO₂, CPP and MAP between the two groups at five minutes after CPR ($P > 0.05$). At 15 minutes and 30 minutes after CPR, PaCO₂ in the A-CPR group was lower than

M-CPR group, while PaO₂, SaO₂, PetCO₂, CPP and MAP in the A-CPR group were higher than M-CPR group ($P < 0.05$), Table-III.

In terms of condition improvement effect, the spontaneous breathing, heart rate, spontaneous circulation, blood pressure recovery time and CPR time of the A-CPR group after treatment were shorter than M-CPR group ($P < 0.05$), as shown in Table-III.

DISCUSSION

Studies have shown that A-CPR was superior to M-CPR.^{8,17,19} However, a meta-analysis of nine prospective studies has suggested that mechanical CPR was inferior to manual CPR in terms of attaining ROSC, and no differences in survival to discharge for in-hospital cardiac arrest patients.¹¹ Khan et al. also reported that manual CPR is more effective in improving hospital discharge or survival at 30 days compared with mechanical CPR.²⁰

In our study, the ROSC rate, successful rate of CPR, 24h survival rate and survival discharge rate of A-CPR group were more time three times higher than the A-CPR, and these findings were statistically significant ($p < 0.05$). Our results are in agreement with the previous study of Chen YS et al.¹⁹ The disparity between the outcomes of the studies is thought to be that it is hard to keep high quality M-CPR as it may be affected by fatigue after 2~3 mins of CPR.²¹ During M-CPR the blood in the right ventricle will enter the pulmonary artery, and the blood in the left ventricle will flow to the whole body. If the pressure continues to be insufficient or the pressure is withdrawn, there will be a negative pressure suction state in the chest, resulting in cardiac perfusion and blood reflux.²² In contrast, using A-CPR ensures that the frequency, depth and strength of extrathoracic cardiac compression are reasonably set according to the specific conditions of patients, while ensuring that the compression is maintained in a constant state, through artificial ventilation. The proportion and frequency of extrathoracic cardiac compression are accurately

Table-II: Comparison of rescue effect between the two groups

Groups	ROSC rate		Successful CPR rate		24h survival rate		Survival and discharge rate	
	AOR(95%CI)	P	AOR(95%CI)	P	AOR(95%CI)	P	AOR(95%CI)	P
M-CPR	1 [reference]		1 [reference]		1 [reference]		1 [reference]	
A-CPR	3.61(1.53, 8.54)	0.003	3.11(1.29, 7.51)	0.012	3.65(1.39, 9.61)	0.009	3.35(1.17, 9.56)	0.024

Table-III: Comparison of blood gas indicators and condition improvement between the two groups.

Outcomes	M-CPR group (n = 51)	A-CPR group (n = 55)	Mann-Whitney U test	P
Blood gas analysis indexes and respiratory dynamics				
5 mins after CPR				
PaCO ₂ (kPa)	8.89±1.27	8.78±1.49	1325.500	0.626
PaO ₂ (kPa)	4.65±1.06	4.50±1.15	1275.500	0.421
SaO ₂ (%)	66.33±8.30	64.31±7.45	1213.000	0.230
PetCO ₂ (mmHg)	14.86±1.94	14.69±1.72	1328.000	0.634
CPP (mmHg)	20.04±3.03	19.78±3.09	1325.500	0.624
MAP (mmHg)	35.15±3.18	34.63±4.25	1273.500	0.412
15 mins after CPR				
PaCO ₂ (kPa)	7.67±1.23	6.16±1.36	610.000	<0.001
PaO ₂ (kPa)	8.03±1.21	9.93±1.28	462.000	<0.001
SaO ₂ (%)	82.78±9.02	91.45±8.17	662.000	<0.001
PetCO ₂ (mmHg)	17.84±2.32	33.52±2.55	0.000	<0.001
CPP (mmHg)	18.58±2.89	38.51±3.44	0.000	<0.001
MAP (mmHg)	35.94±3.67	57.89±3.70	0.000	<0.001
30 mins after CPR				
PaCO ₂ (kPa)	6.17±1.18	3.65±1.33	254.000	<0.001
PaO ₂ (kPa)	8.66±1.22	12.39±1.34	27.000	<0.001
SaO ₂ (%)	88.76±9.25	96.83±8.34	707.000	<0.001
PetCO ₂ (mmHg)	17.02±2.63	35.65±2.94	0.000	<0.001
CPP (mmHg)	19.33±3.38	39.92±3.62	0.000	<0.001
MAP (mmHg)	37.19±3.83	59.14±3.51	0.000	<0.001
Improvement effect				
Spontaneous breathing recovery time	22.68±3.77	14.92±2.29	97.500	<0.001
Heart rate recovery time	16.78±2.94	10.76±1.91	132.500	<0.001
Spontaneous circulation recovery time	47.58±4.46	34.82±3.01	19.500	<0.001
Blood pressure recovery time	61.80±5.19	46.16±3.46	12.500	<0.001
CPR time	33.53±4.66	23.82±2.90	120.000	<0.001

preset to provide patients with constant and lasting ventilation support, maintain the diastolic and systolic time ratio of 1:1, improve the quality of oxygen supply and blood supply, help to improve the rescue effect.²³⁻²⁵

Several studies have shown that the use of CPR auxiliary mechanical equipment not only improved the effectiveness of chest compression,

but also improved hemodynamics and short-term survival.^{26,27} Our study demonstrated that at 15 and 30 minutes after CPR, PaCO₂ in the A-CPR group was lower than M-CPR group, while PaO₂, SaO₂, PetCO₂, CPP and MAP were higher than M-CPR group ($P<0.05$), indicating A-CPR was more efficient in improving blood gas analysis indexes and respiratory dynamics compared with

the M-CPR, these results are consistent with the research results of Zhang C et al.²⁸

In this study, the spontaneous breathing, heart rate, spontaneous circulation, blood pressure recovery time and CPR time of the A-CPR group after treatment were shorter than M-CPR group ($P < 0.05$), indicating that the application effect of A-CPR rescue in improving the condition is also better than M-CPR. The use of A-CPR, therefore, may prevent continuous loss of brain and heart function and irreversible death by timely supplying blood to the patient's brain and heart, and create more opportunities and favorable conditions for later defibrillation and drug treatment. This will further improve the rescue effect and the prognosis, promote the remission of the disease, and shorten the time of recovery of spontaneous breathing, heart rate, spontaneous circulation, blood pressure and CPR.²⁹ Even though the A-CPR increases the diastolic blood pressure and improve the physiologic status, it does not provide strong evidence that A-CPR is better than M-CPR because systematic post-cardiac arrest care after ROSC also an impact on patient survival.³⁰

Limitation of the study: First, this a retrospective, single center observational study without randomization. It includes a small number of cases which increased the chance of assuming false promises to be true.³¹ Improved designs with large-scale samples are needed in future studies. Second, even though age, gender and cause of arrest are controlled in our study, other confounders like BMI and health status may also influence the outcomes. Third, since post-cardiac arrest may affect patient survival, post-cardiac arrest care for the patients was not matched and analyzed in this study.³⁰ Fourth, the patients included in this study were only emergency patients in our hospital. The treatment level and staffing can only partially reflect the overall treatment level of the emergency medicine department of the country. Whether this conclusion can be extended to other emergency medicine units still needs further research.

CONCLUSION

The application effect of A-CPR in the rescue of cardiac and respiratory arrest, the improvement of blood gas analysis indexes, respiration and condition improvement are more significant than M-CPR.

REFERENCES

1. Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, et al. On behalf of the American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2020 update: a report from the American Heart Association. *Circulation*. 2020;141:e139–e596.
2. Holmberg MJ, Ross CE, Fitzmaurice GM, Chan PS, Duval-Arnould J, Grossestreuer AV, et al. American Heart Association's Get With The Guidelines—Resuscitation Investigators. Annual Incidence of Adult and Pediatric In-Hospital Cardiac Arrest in the United States. *Circ Cardiovasc Qual Outcomes*. 2019;12:e005580.
3. Merchant RM, Topjian AA, Panchal AR, Cheng A, Aziz K, Berg KM, et al. Adult Basic and Advanced Life Support, Pediatric Basic and Advanced Life Support, Neonatal Life Support, Resuscitation Education Science, and Systems of Care Writing Groups. Part 1: Executive Summary: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2020;142(16_suppl_2):S337-S357. doi: 10.1161/CIR.0000000000000918
4. Zhou GJ, Jin P, Jiang SY. Gastric perforation following improper cardiopulmonary resuscitation in out-of-hospital cardiac arrest. *Pak J Med Sci*. 2020;36(2):296-298. doi: 10.12669/pjms.36.2.1363
5. Colak T, Tekten BO. Factors affecting survival and neurological outcomes for patients who underwent cardiopulmonary resuscitation. *J Pak Med Assoc*. 2020;70(8):1376-1380. doi: 10.5455/JPMA.29598
6. Vahedian-Azimi A, Rahimibashar F, Miller AC. A comparison of cardiopulmonary resuscitation with standard manual compressions versus compressions with real-time audiovisual feedback: A randomized controlled pilot study. *Int J Crit Illn Inj Sci*. 2020;10(1):32-37. doi: 10.4103/IJCIIS.IJCIIS_84_19
7. Fumagalli F, Silver AE, Tan Q, Zaidi N, Ristagno G. Cardiac rhythm analysis during ongoing cardiopulmonary resuscitation using the Analysis During Compressions with Fast Reconfirmation technology. *Heart Rhythm*. 2018;15(2):248-255. doi: 10.1016/j.hrthm.2017.09.003
8. Obermaier M, Zimmermann JB, Popp E, Weigand MA, Weiterer S, Dinse-Lambracht A, et al. Automated mechanical cardiopulmonary resuscitation devices versus manual chest compressions in the treatment of cardiac arrest: protocol of a systematic review and meta-analysis comparing machine to human. *BMJ Open*. 2021;11(2):e042062. doi: 10.1136/bmjopen-2020-042062
9. Gates S, Quinn T, Deakin CD, Blair L, Couper K, Perkins GD. Mechanical chest compression for out of hospital cardiac arrest: Systematic review an meta-analysis. *Resuscitation*. 2015;94:91-97.
10. Bonnes JL, Brouwer MA, Navarese EP, Verhaert DVM, Verheugt FWA, Smeets JLRM, et al. Manual cardiopulmonary resuscitation versus CPR including a mechanical chest compression device in out-of-hospital cardiac arrest: A comprehensive meta-analysis from randomized and observational studies. *Ann Emerg Med*. 2016;67:349-360.e3
11. Li H, Wang D, Yu Y, Zhao X, Jing X. Mechanical versus manual chest compressions for cardiac arrest: a systematic review and meta-analysis. *Scand J Trauma Resusc Emerg Med*. 2016;24:10.

12. von Elm E, Altman DG, Egger M, Pocock SJ, Gotsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. (Available on: <https://www.equator-network.org/>)
13. Kattwinkel J, Perlman JM, Aziz K, Colby C, Fairchild K, Gallagher J, et al. Part 15: neonatal resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122(18 Suppl 3):S909-919. doi: 10.1161/CIRCULATIONAHA.110.971119
14. Neumar RW, Shuster M, Callaway CW, Gent LM, Atkins DL, Bhanji F, et al. Part 1: Executive Summary: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(18 Suppl 2):S315-367. doi: 10.1161/CIR.0000000000000252
15. Lee SY, Hong KJ, Shin SD, Ro YS, Song KJ, Park JH, et al. The effect of dispatcher-assisted cardiopulmonary resuscitation on early defibrillation and return of spontaneous circulation with survival. *Resuscitation*. 2019;135:21-29. doi: 10.1016/j.resuscitation.2019.01.004
16. Lv JH, Wang D, Zhang MN, Bai ZH, Sun JL, Shi Y, et al. The related factors for the recovery and maintenance time of sinus rhythm in hospitalized patients with cardiopulmonary resuscitation: A single-center retrospective case-control study. *Medicine (Baltimore)*. 2019;98(5):e14303. doi: 10.1097/MD.00000000000014303
17. Crowley CP, Wan ES, Saliccioli JD, Kim E. The Use of Mechanical Cardiopulmonary Resuscitation May Be Associated With Improved Outcomes Over Manual Cardiopulmonary Resuscitation During Inhospital Cardiac Arrests. *Crit Care Explor*. 2020;2(11):e0261. doi: 10.1097/CCE.0000000000000261
18. Wang X, Ji X. Sample Size Estimation in Clinical Research: From Randomized Controlled Trials to Observational Studies. *Chest*. 2020;158(15):S12-S20. doi: 10.1016/j.chest.2020.03.010
19. Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, et al. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. *Lancet Lond Engl*. 2008;372(9638):554-561. doi: 10.1016/S0140-6736(08)60958-7
20. Khan SU, Lone AN, Talluri S, Khan MZ, Khan MU, Kaluski E. Efficacy and safety of mechanical versus manual compression in cardiac arrest - A Bayesian network meta-analysis. *Resuscitation*. 2018;130:182-188. doi: 10.1016/j.resuscitation.2018.05.005
21. McDonald CH, Heggie J, Jones CM, Thorne CJ, Hulme J. Rescuer fatigue under the 2010 ERC guidelines, and its effect on cardiopulmonary resuscitation (CPR) performance. *Emerg Med J*. 2013;30:623-630.
22. Hirano Y, Kondo Y, Sueyoshi K, Okamoto K, Tanaka H. Early outcome prediction for out-of-hospital cardiac arrest with initial shockable rhythm using machine learning models. *Resuscitation*. 2021;158:49-56. doi: 10.1016/j.resuscitation.2020.11.020
23. Zamir Q, Nadeem A, Rizvi AH. Awareness of cardiopulmonary resuscitation in medical-students and doctors in Rawalpindi-Islamabad, Pakistan. *J Pak Med Assoc*. 2012;62(12):1361-1364.
24. Metzger AK, Herman M, McKnite S, Tang W, Yannopoulos D. Improved cerebral perfusion pressures and 24-hr neurological survival in a porcine model of cardiac arrest with active compression-decompression cardiopulmonary resuscitation and augmentation of negative intrathoracic pressure. *Crit Care Med*. 2012;40(6):1851-1856. doi: 10.1097/CCM.0b013e318246b9ad
25. Kim YW, Cha KC, Kim YS, Cha YS, Kim H, Lee KH, et al. Kinetic analysis of cardiac compressions during cardiopulmonary resuscitation. *J Crit Care*. 2019;52:48-52. doi: 10.1016/j.jcrc.2019.04.003
26. Wigginton JG, Miller AH, Benitez FL, Pepe PE. Mechanical devices for cardiopulmonary resuscitation. *Curr Opin Crit Care*. 2005;11(3):219-223. doi: 10.1097/01.ccx.0000163720.23558.36
27. Magliocca A, Olivari D, De Giorgio D, Zani D, Manfredi M, Boccardo A, et al. LUCAS Versus Manual Chest Compression During Ambulance Transport: A Hemodynamic Study in a Porcine Model of Cardiac Arrest. *J Am Heart Assoc*. 2019;8(1):e011189. doi: 10.1161/JAHA.118.011189
28. Zhang C, Wang Y, Liu H, Hao A, Xun J, Meng Q. Comparative study for effects of bare-handed CPR with Thumper cardiopulmonary resuscitator CPR in emergency department based on "the Utstein style". *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue*. 2017;29(10):937-939. doi: 10.3760/cma.j.issn.2095-4352.2017.10.015
29. Coggins AR, Nottingham C, Byth K, Ho KR, Aulia FA, Murphy M, et al. Randomised controlled trial of simulation-based education for mechanical cardiopulmonary resuscitation training. *Emerg Med J*. 2019;36(5):266-272. doi: 10.1136/emered-2017-207431
30. Peberdy MA, Callaway CW, Neumar RW, Geocadin RG, Zimmerman JL, Donnino M, et al. American Heart Association. Part 9: post-cardiac arrest care: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010 Nov 2;122(18 Suppl 3):S768-86. doi: 10.1161/CIRCULATIONAHA.110.971002
31. Faber J, Fonseca LM. How sample size influences research outcomes. *Dental Press J Orthod*. 2014;19(4):27-29. doi: 10.1590/2176-9451.19.4.027-029.ebo

Authors' Contributions: HN conceived and designed the study. MG and SY collected the data and performed the analysis. HN was involved in the writing of the manuscript and is accountable for the integrity of the study. All authors have read and approved the final manuscript.

Authors:

1. Mengying Gao, Department of Emergency,
 2. Huiping Niu, Department of Endoscopy Center,
 3. Shuang Yuan, Department of Intensive Care Unit, Shandong Provincial Third Hospital, Cheeloo College of Medicine, Shandong University, Jinan, China.
- 1, 2: The Second Hospital of Hebei Medical University, Hebei, China.