

Association Between use of a Single-Piston CPR Device in the Resuscitation Process and the Short-Term Survival of OHCA Patients

Pawaruj Rirermsoonthorn[✉], Theerapon Tangsuwanaruk[✉] and Borwon Wittayachamnankul[✉]

Department of Emergency Medicine, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand

Correspondence:

Borwon Wittayachamnankul, MD, PhD, Department of Emergency Medicine, Faculty of Medicine, Chiang Mai University, 110 Inthavaroros Road, Sri Phum, Muang, Chiang Mai 50200, Thailand
E-mail: borwon.witt@cmu.ac.th

Received: December 4, 2023;

Revised: May 14, 2024;

Accepted: May 14, 2024

© The Author(s) 2024. Open Access



This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made.

ABSTRACT

OBJECTIVE There is still a lack of evidence regarding the efficacy of using a single point piston without suction cup mechanical cardiopulmonary resuscitation (CPR) device in the resuscitation of out of hospital cardiac arrest (OHCA) cases in a moving ambulance setting. The aim of this study is to evaluate and compare short term survival rate return of spontaneous circulation (ROSC) of emergency medical service (EMS) delivered to OHCA patients receiving single point piston without a suction cup mechanical CPR device and manual CPR.

METHODS This case control study was conducted using data on OHCA patients between 1 January 2017 and 31 March 2020 using part of the Pan-Asian Resuscitation Outcomes Study (PAROS) data. Cases were classified as ROSC or no ROSC. Logistic regression analysis was used for the multi-variable analysis of the primary objective.

RESULTS A total of 206 cases were included in this study, 68 ROSC cases and 138 no ROSC cases. The multivariable analysis found no significant difference in the ROSC rate of EMS delivered OHCA patients who received only manual CPR and patients who received the mechanical CPR either in the EMS (OR: 0.49, 95% confidence interval [CI]: 0.13-1.78) or the emergency department (ED) (AOR: 16.05, 95% confidence interval [CI]: 0.18-1435.78).

CONCLUSIONS The use of the single point piston without suction cup CPR device in OHCA cases was not found to be inferior in terms of ROSC rate compared with manual CPR. Also, potential benefits in a prehospital setting could be provided by the device use, e.g., fewer staff required in the EMS. Use of the device should be considered in appropriate situations.

KEYWORDS cardiopulmonary resuscitation; heart arrest; mechanical chest compressions

INTRODUCTION

High-quality cardiopulmonary resuscitation (CPR), according to current international guidelines, is emphasized as being an important factor associated with desirable outcomes in patients with cardiac arrest and classified by certain criteria (1). Despite being highlighted, a body of evidence

has shown that there are potential problems that may prevent the provision of high-quality CPR through the conventional method (manual compression) (2, 3). To overcome the limitations of conventional manual CPR, mechanical chest compression devices were introduced as an alternative. Although several studies have found that

mechanical CPR might be able to provide more high-quality chest compression than manual CPR, (4, 5) current evidence still does not support the existence of any difference in out-of-hospital cardiac arrest (OHCA) patient survival between the two protocols (6, 7). CPR with mechanical chest compression currently provides no clear advantage over CPR with conventional manual chest compression in general situations, and current international guidelines still suggest the use of manual chest compression in most situations when CPR is indicated (1).

A few circumstances may cause performance of CPR to be more challenging. These include operating in a moving ground ambulance where performing CPR poses a great risk to the rescuers (8). The mechanical chest compression device, which has been proven to be capable of delivering high-quality CPR, is recommended by international guidelines as a reasonable alternative to the manual CPR (1).

There is a gap of knowledge, as suggested by the Cochrane review, regarding mechanical CPR efficacy in some special circumstances where sustained high-quality CPR is needed and in situations where manual CPR is considered to be difficult to provide or not safe for the rescuers such performing CPR in a moving emergency medical system (EMS) vehicle (7). Most current studies have evaluated only the Autopulse (Zoll Medical, Chelmsford, MA, USA) load distributing band device and the LUCAS (Physio Control Inc./Jolife AV, Lund, Sweden) piston device with suction cup, and other similar kinds of devices including single point piston devices without suction cup, e.g., Lifeline ARM (Defibtech, Guilford, CT, USA); however, additional information regarding their efficiency in providing favorable outcomes and improving survival is needed. The aim of this study is to compare the short-term survival rate (ROSC) of EMS delivered to OHCA patients who received single point piston mechanical CPR device and those who received manual CPR.

METHODS

Setting and study design

This case-control study used the Maharaj Nakorn Chiang Mai Hospital's emergency department (ED) database which is part of the Pan-Asian Resuscitation Outcomes Study (PAROS) (9). The present

study followed the Utstein-style template and adhered to all relevant guidelines outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement. Data about EMS and ED care of OHCA patients who arrived during the study period (January 1, 2017 through March 31, 2020) was collected. During the study period, the use of the Lifeline ARM (Defibtech, Guilford, CT, USA), a single point piston mechanical CPR device without suction cup, was documented. EMS providers had been trained to use the device by a product specialist. The decision to use the device was based entirely on the judgement of the physician in charge of each case. Recorded cases were categorized into ROSC (case) and no ROSC (control) groups. Inclusion criteria were non-traumatic cardiac arrest cases age at least 18 years who were brought to the hospital's ED by EMS. Cases were excluded if the patient's age was unknown, if data about ROSC use was not recorded, and if the patient did not receive any CPR.

The study protocol was approved by the Research Ethics Committee, Faculty of Medicine, Chiang Mai University (Permit No. EXEMPTION-8008/64/0) and the Thai Clinical Trials Registry Committee, Medical Research Foundation of Thailand (Permit No. TCTR20210401002).

Variables

Short-term outcome data, including use of ROSC at the scene, in the EMS and at the ED was collected and used for assigning patients to either the case or the control group. Potential confounders, e.g., data on prognostic factors that may have influenced the resuscitation outcome, including age of the patient, medical history, response time, duration of OHCA events, witnesses to the OHCA events, use of AED by bystanders, the use of CPR by bystanders, location where the arrest occurred, initial arrest rhythm, if defibrillation was applied, if endotracheal intubation was done, and duration of CPR was collected. For the exposure to a mechanical CPR device, data on the use of a mechanical CPR device both in the EMS and the ED was also obtained.

Definitions

In this study, ROSC, in concordance with the Utstein-style criteria, is defined as a persistent

palpable pulse for at least 20 seconds (10). The duration of CPR is presumed to be the interval between CPR initiation and the first ROSC, or the decision to cease the resuscitation attempt. For cases where the time of CPR initiation was unknown or where the initial CPR resuscitation was done by a bystander, the time was assumed to be either the time the collapse was witnessed or the time of the emergency call. For cases that did not receive bystander CPR, the time of EMS arrival at scene was considered to be the time of CPR initiation.

Sample size

The sample size was calculated using the Stata version 16 (Stata Corp LLC, College Station, TX, USA) asymptotic z test (sample size estimation with odds ratio) based on data from a comparable study (11). As a case control study, patients were sorted into 2 groups, ROSC achieved (case) and no ROSC achieved (control). Parameters for the study size calculation were set as follows: power at 80%, alpha error at 0.05 (two-sided), ratio between case and control 1:1, probability of exposure among control patients 0.44, odds ratio of exposure in cases relative to controls 2.66. The number of cases calculated using that formula was 69 per group. A 20% dropout rate was added to the calculated total N of 138, resulting in the planned total sample size of 173.

Statistical analysis

Descriptive statistics were used for the outcome report. Frequencies and percentages were used to describe categorical data, while mean and standard deviation (SD.) or median and inter-quartile range (IQR) were used to describe continuous data. The independent Student's t-test, the two-sample Wilcoxon rank-sum test and the chi-square test were used as appropriate for the comparison of each of the baseline characteristics between the case and control groups. As this is a retrospective study, it was not feasible to allocate or randomize the exposure equally between the study groups. Also, each decision regarding use of the mechanical CPR was based entirely on the on-site judgement of the attending resuscitation team. The issues mentioned above could have resulted in the occurrence of selection bias. For that reason, statistical methods to lessen the effect

of such possible bias, e.g., logistic regression analysis were used. Univariable and multivariable analysis was done using logistic regression analysis.

RESULTS

Baseline characteristics of studied cases

Based on the data collected as part of the PAROS between January 1, 2017 and March 31, 2020 in which 329 cases were recorded, 109 of those cases were excluded as the exclusion criteria were met. After exclusion there were 74 ROSC cases and 146 no ROSC cases. Of those, a further 14 cases (6 ROSC cases and 8 no ROSC cases) were excluded due to insufficient data regarding the use of a mechanical CPR device. Finally, 206 patients were included in the analysis, consisting of 68 ROSC cases and 138 no ROSC cases (Figure 1). The mean age of the ROSC group was 49.2 ± 24.7 years while in the no ROSC group the mean age was comparatively older at 56.3 ± 20.4 years ($p = 0.033$). A greater proportion of the ROSC patients were covered by the Thai Government Universal Health Care Coverage scheme than those who did not have ROSC (66.2% vs. 42.8%; $p = 0.002$). There were more cases witnessed by bystanders and more cases with bystander CPR in the ROSC group than in the no ROSC group (73.5% vs. 45.6%, $p = 0.001$ and 45.6% vs. 20.3%, $p < 0.001$), respectively). The total number of instances of using mechanical CPR was 27 out of 206 (13.1%). A higher incidence of mechanical CPR deployment was found in the no ROSC group compared to the ROSC group in all three health care settings: unspecified (17.4% vs. 4.4%; $p = 0.031$), in the EMS (8.7% vs. 4.4%; $p = 0.275$), and at the ED (14.5% vs. 2.9%; $p = 0.023$). In addition, a higher incidence of shockable initial arrest rhythm was found in the ROSC patients than in the no ROSC patients (17.7% vs. 12.3%; $p = 0.005$). More patients who did not have ROSC received defibrillation than no ROSC patients (50.7% vs. 35.3%; $p = 0.038$). The median CPR duration was lower in the ROSC group compared to the no ROSC group (22 (IQR: 9, 40) vs. 30 (IQR=21,45) minutes; $p = 0.024$). Additional details are shown in Table 1.

Univariable and multivariable analysis

Results of the univariable and multivariable logistic regression analysis of factors potentially

Table 1. Comparison of baseline characteristics of ROSC and no ROSC cardiac arrest patients both in and outside the hospital

Variable	ROSC n=68 (%)	No ROSC n=138 (%)	p-value
Age (year)			
Mean±SD	49.2±24.7	56.3±20.4	0.033
Gender			
Female	20 (29.4)	44 (31.9)	0.718
Male	48 (70.6)	94 (68.1)	
Race			
Thai	59 (86.8)	119 (86.2)	0.916
Other	9 (13.2)	19 (13.8)	
Past medical history			
Cardiac disease	5 (7.4)	17 (12.3)	0.711
Cancer	2 (2.9)	6 (4.3)	0.547
Hypertension	22 (32.4)	28 (20.3)	0.080
Diabetes	12 (17.6)	20 (14.5)	0.327
Dyslipidemia	7 (10.3)	8 (5.8)	0.305
Renal disease	8 (11.8)	12 (8.7)	0.348
Respiratory disease	3 (4.4)	13 (9.4)	0.718
Stroke	4 (5.9)	8 (5.8)	0.477
HIV infection	0 (0.0)	3 (2.2)	0.587
Other	18 (26.5)	23 (16.7)	0.130
None	2 (2.9)	4 (2.9)	0.986
Unknown	34 (50.0)	62 (44.9)	0.531
Arrest witnessed			
Yes	50 (73.5)	67 (45.6)	0.001
No	18 (26.5)	71 (51.5)	
CPR by bystander			
Yes	31 (45.6)	28 (20.3)	<0.001
No	37 (54.4)	110 (79.7)	
AED applied by bystander			
Yes	4 (5.9)	8 (5.8)	0.513
No	63 (92.6)	131 (94.9)	
Arrest location			
Home	23 (33.8)	79 (57.3)	0.002
Public place	45 (66.2)	59 (42.8)	
Response time (minutes)			
Median (IQR)	4 (2,7)	5 (2,9)	0.140
CPR duration (minutes)			
Median (IQR)	22 (9,40)	30 (21,45)	0.024
Arrest time			
Day	34 (50.8)	67 (49.3)	0.843
Night	33 (49.2)	69 (50.7)	
ETI			
Yes	66 (97.1)	136 (98.6)	0.475
No	2 (2.9)	2 (1.4)	
First arrest rhythm			
Unshockable rhythm	23 (33.8)	77 (55.8)	0.005
Shockable rhythm	12 (17.7)	17 (12.3)	
Defibrillation done			
Yes	24 (35.3)	70 (50.7)	0.038
No	44 (64.7)	68 (49.3)	

Table 1. Comparison of baseline characteristics of ROSC and no ROSC cardiac arrest patients both in and outside the hospital (continued)

Variable	ROSC n=68 (%)	No ROSC n=138 (%)	p-value
Mechanical CPR done prehospitally/ at the ED			
Yes	3 (4.4)	24 (17.4)	0.031
No	65 (95.6)	114 (82.6)	
Mechanical CPR done in the EMS vehicle			
Yes	3 (4.4)	12 (8.7)	0.275
No	65 (95.6)	126 (91.3)	
Mechanical CPR done at the ED			
Yes	2 (2.9)	20 (14.5)	0.023
No	66 (97.1)	118 (85.5)	

Data are presented as mean $\pm$ standard deviation (SD), median (IQR) or number (%).

CPR, Cardiopulmonary resuscitation; ETI, endotracheal intubation; AED, automated external defibrillator; CPR duration, defined as the time from initiation of CPR by emergency medical technicians to either return of spontaneous circulation or death; Night, 7.00 p.m. to 6.59 a.m.; Day, 7.00 a.m. to 6.59 p.m.; ED, emergency department; EMS, emergency medical service

Table 2. Univariable and multivariable analysis of factors potentially related to ROSC in cardiac arrest patients both in and outside of the hospital

Variable	Univariable		Multivariable	
	OR (95%CI)	p-value	AOR (95%CI)	p-value
Age	0.98 (0.97-0.99)	0.031	0.95 (0.90-0.99)	0.027
Male sex	1.12 (0.60-2.12)	0.718	-	-
Past history (cardiac disease)	1.05 (0.78-1.44)	0.711	-	-
Arrest witnessed	2.94 (1.56-5.55)	0.001	0.88 (0.14-5.72)	0.895
Bystander CPR applied	3.29 (1.75-6.20)	< 0.001	11.01 (1.09-110.70)	0.045
Bystander AED applied	1.49 (0.45-4.86)	0.513	-	-
Location of OHCAs (public)	2.62 (1.43-4.80)	0.002	5.95 (0.95-37.13)	0.056
CPR duration	0.96 (0.93-0.99)	0.027	0.95 (0.88-0.99)	0.047
Any defibrillation done	0.53 (0.29-0.96)	0.038	0.51 (0.06-4.12)	0.526
Shockable first arrest rhythm	1.58 (1.15-2.18)	0.005	3.49 (0.88-13.82)	0.076
Mechanical CPR (EMS)	0.49 (0.13-1.78)	0.275	-	-
Mechanical CPR (ED)	0.18 (0.04-0.79)	0.023	16.05 (0.18-1435.78)	0.226

CI, confidence interval; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; OHCAs, out of hospital cardiac arrest; EMS, emergency medical service; ED, emergency department; OR, crude odds ratio; AOR, adjusted odds ratio (adjusted for age, sex, past history (cardiac disease), witnessed arrest, bystander CPR, bystander AED applied, location of OHCAs (public), CPR duration, any defibrillation done, shockable first arrest rhythm, mechanical CPR (EMS) and mechanical CPR (ED)).

related to successful ROSC in OHCA patients are shown in Table 2. Of the 12 variables (age, male sex, past history (cardiac disease), arrest witnessed, bystander CPR, bystander AED applied, location of OHCAs (public), CPR duration, use of defibrillation, shockable first arrest rhythm and mechanical CPR (EMS) and mechanical CPR (ED), three variables, age (AOR = 0.95, 95% confidence

interval [CI]: 0.90-0.99), bystander CPR (AOR: 11.01, 95% confidence interval [CI]: 1.75-6.20), and CPR duration (AOR: 0.95, 95% confidence interval [CI]: 0.88-0.99) were found to be significantly associated with ROSC in OHCA patients. The use of mechanical CPR, either at the ED or in the EMS, was not found to be significantly associated with ROSC in OHCA patients.

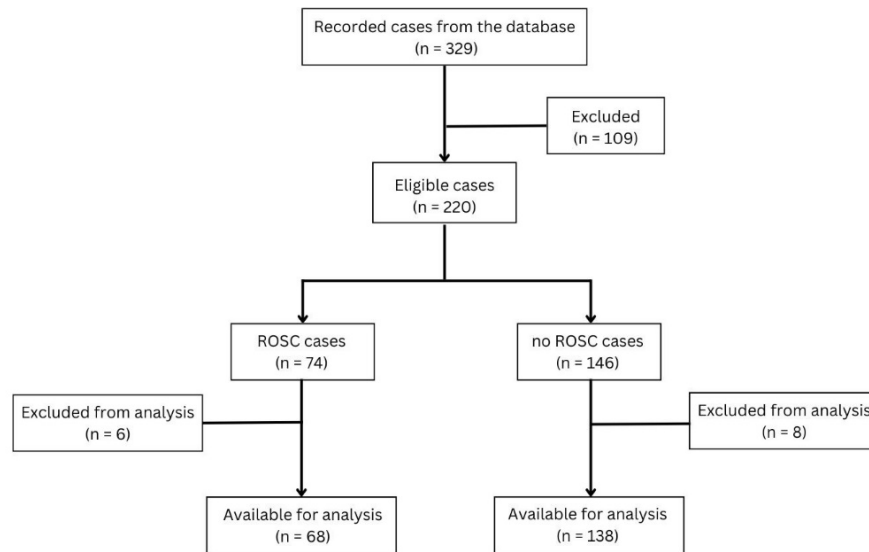


Figure 1. Flow chart of the study

DISCUSSION

Despite a body of evidence showing that performing CPR in a prehospital setting, e.g., in a moving ambulance, can be more challenging for achieving high-quality CPR using manual chest compression compared to mechanical chest compression, (5, 8, 12) the present study did not find any significant difference. Our findings do not support the hypothesis of an improved ROSC rate in patients receiving mechanical CPR. This discordance might be explainable by several factors, including unrecorded device application time, unrecorded pauses in chest compression for device deployment, prolonged duration of chest compression, varying distance from the site to the ED, difference in the urgency for each patient delivery and other surrounding factors, e.g., the patients' family, site characteristics and differences in attending staff decisions. Additionally, there is currently a lack of evidence regarding the survival outcome of single point piston CPR devices without suction cup use in the EMS.

In both patients who achieved ROSC and patients who did not achieve ROSC, having bystander CPR done, younger age of the patient and shorter CPR duration were found to be significantly associated with ROSC, a finding consistent with some previous studies (13, 14).

Although the present study's results are consistent with the recently updated Cochrane review comparing mechanical CPR and manual CPR efficacy, (7) the mechanism of this study's referenced device was different from those in the review

(compression only vs. compression-decompression and load distribution band). That difference could potentially have affected the comparability of the two studies' results.

Some other studies' findings were contrary to the results of this study. Anatharaman et al. reported that early use of a mechanical CPR device (LUCAS-2) is associated with a higher incidence of achieving ROSC (15). Similarly, a study by Seewald et al. suggested there is an improved ROSC rate in OHCA patients receiving mechanical CPR (LUCAS and Autopulse) (16). The incongruity of these results and those of the present study may be due to differences in the mechanical CPR device used, the number of witnessed cases, the duration of device application and the number of the mechanical CPR devices used.

Despite the lack of supportive results regarding the improved survivability of OHCA patients who received mechanical CPR, it might still have a role in the resuscitation of OHCA patients. Some non-clinical studies have reported that more consistent high-quality CPR was achieved with mechanical CPR compared to manual CPR in the setting of a moving ambulance (4, 8). That may help reduce the number of staff required for the resuscitation of OHCA patients in an ambulance. It may also provide increased safety for EMS staff who would otherwise sometimes have to do manual CPR in potentially harmful situations, including in a moving ambulance. As this study's results suggest, mechanical CPR has no significant disadvantages compared to conventional manual

CPR, so it may be an appropriate substitute for manual CPR in situations where continuity of CPR is required and where performing manual CPR either poses a threat to the CPR provider's safety or where it may be less likely to yield high quality CPR according to the current standard guidelines and in situations where it is preferable to use fewer staff for resuscitation and transportation of emergency patients, e.g., during the present COVID-19 pandemic.

Further investigative comparison of mechanical and manual CPR in terms of safety and duration of use of the mechanical chest compression device is needed. Future studies should address the potential benefits of mechanical CPR in terms of safety either via the use of questionnaires or other methods and should include the precise time during which the mechanical CPR was done. Additionally, the present study was conducted using cases in urban and nearby areas of Chiang Mai, Thailand so the majority of this study's population were Thai. For these reasons, interpretation of the results of the present study should be done with caution.

Limitations

This study has some limitations. First, this was a retrospective single centered study, so the study could only reach as far as the pre-existing data provided, and there was a portion of the population whose first arrest rhythm was not recorded. Additionally, data on the time during which the mechanical chest compression device was applied either at the scene or in the EMS was not available. A few additional factors, e.g., the limited number of available mechanical CPR devices at the study hospital's ED, could have led to unequal distribution of the use of the device among cases and thus could have resulted in selection bias. The MCPR devices in this study were not significantly different from models which have been thoroughly evaluated in many previous studies. There was also limited data regarding EMS actions which may have affected the outcomes. Also, the small number of cases receiving mechanical CPR in this study could have resulted in an overestimated adjusted odds ratio in the multivariable analysis of the association with ROSC. Lastly, in this study, the number of mechanical CPR devices used was

rather small which may have affected the power of the statistical analysis.

CONCLUSIONS

Despite the lack of significant evidence of benefits of mechanical CPR over traditional manual CPR, this does not argue against the use of the device in OHCA patients. The mechanical CPR devices have some potential benefits which may help facilitate the resuscitation process of OHCA patients, especially in the prehospital setting. Benefits include a reduced number of staff required for the EMS, increased EMS staff safety and more consistent CPR efficacy in a moving EMS. Use of the single piston mechanical CPR device should be considered in circumstances where their benefits would be an asset to patients and/or hospital staff.

ACKNOWLEDGMENTS

We would like to thank Miss Rudklao Sairai and colleagues at the Research Unit of the Department of Emergency Medicine, Chiang Mai University for facilitating this study.

FUNDING

The authors received no funding.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to report.

ADDITIONAL INFORMATION

Author contributions statement

P.R.: review, editing, conceptualization (lead), writing – original draft (lead); B.W.: formal analysis (lead), methodology (lead), software, writing – review and editing (equal); T.T.: conceptualization (supporting), writing – original draft (supporting), writing – review and editing (equal).

Informed consent

Due to the retrospective nature of the study, the need of informed consent was waived by the Research Ethics Committee, Faculty of Medicine, Chiang Mai University.

Consent for publication

Not applicable

REFERENCES

- Callaway C, Soar J, Aibiki M, Böttiger B, Brooks S, Deakin C, et al. Part 4: Advanced Life Support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2015;132(Supplementary_1): S84-145.
- Sugerman N, Edelson D, Leary M, Weidman E, Herzberg D, Vanden Hoek T, et al. Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study. *Resuscitation*. 2009;80:981-4.
- Stiell I, Brown S, Nichol G, Cheskes S, Vaillancourt C, Callaway C, et al. What is the optimal chest compression depth during out-of-hospital cardiac arrest resuscitation of adult patients? *Circulation*. 2014;130: 1962-70.
- 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:e011189. PubMed PMID: 30590977
- Szarpak L, Truszcwski Z, Czyzewski L, Frass M, Robak O. CPR using the lifeline ARM mechanical chest compression device: a randomized, crossover, manikin trial. *Am J Emerg Med*. 2017;35:96-100.
- Bonnes J, Brouwer M, Navarese E, Verhaert D, Verheugt F, Smeets J, 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.
- Wang P and Brooks S. Mechanical versus manual chest compressions for cardiac arrest. *Cochrane Database Syst Rev*. 2018;8:CD007260. PubMed PMID: 30125048
- Fox J, Fiechter R, Gerstl P, Url A, Wagner H, Lüscher T, et al. Mechanical versus manual chest compression CPR under ground ambulance transport conditions. *Acute Card Care*. 2013;15:1-6.
- Couper K, Quinn T, Lall R, Devrell A, Orriss B, Seers K, et al. Mechanical versus manual chest compressions in the treatment of in-hospital cardiac arrest patients in a non-shockable rhythm: a randomised controlled feasibility trial (COMPRESS-RCT). *Scand J Trauma Resusc Emerg Med* 2018;26:70. PubMed PMID: 30165909
- Perkins G, Jacobs I, Nadkarni V, Berg R, Bhanji F, Barent D, 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*. 2015;132:1286-300.
- Gao C, Chen Y, Peng H, Chen Y, Zhuang Y and Zhou S. Clinical evaluation of the autopulse automated chest compression device for out-of-hospital cardiac arrest in the northern district of Shanghai, China. *Arch Med Sci*. 2016;12:563-570.
- Truszcwski Z, Szarpak L, Kurowski A, Evrin T, Madziła M and Czyzewski L. Mechanical chest compression with the LifeLine ARM device during simulated CPR. *Am J Emerg Med*. 2016;34:917. PubMed PMID: 26924321
- Czapla M, Zielińska M, Kubica-Cielińska A, Diakowska D, Quinn T and Karniej P. Factors associated with return of spontaneous circulation after out-of-hospital cardiac arrest in Poland: a one-year retrospective study. *BMC Cardiovasc Disord*. 2020;20:288. PubMed PMID: 32532201
- Navab E, Esmaeili M, Poorkhorshidi N, Salimi R, Khazaei A, Moghimbeigi A. Predictors of out of hospital cardiac arrest outcomes in pre-hospital settings; a retrospective cross-sectional study. *Arch Acad Emerg Med*. 2019;7:36. PubMed PMID: 31555766
- Anantharaman V, Ng BL, Ang SH, Lee CY, Leong SH, Ong ME, et al. Prompt use of mechanical cardiopulmonary resuscitation in out-of-hospital cardiac arrest: the MECCA study report. *Singapore Med J*. 2017; 58:424-31.
- Seewald S, Obermaier M, Lefering R, Bohn A, Georgieff M, Muth CM, et al. Application of mechanical cardiopulmonary resuscitation devices and their value in out-of-hospital cardiac arrest: A retrospective analysis of the German Resuscitation Registry. *PLoS One*. 2019;14:e0208113. PubMed PMID: 31555766