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Original Article

Effectiveness of mechanical chest compression for out-of-hospital cardiac arrest patients in an emergency department

Ching-Kuo Lin [a,b,c], Mei-Chin Huang [d], Yu-Tung Feng [e], Wei-Hsuan Jeng [a,b,c], Te-Cheng Chung [a,b,c], Yu-Wa Lau [a,b,c], Kuang-I Cheng [f,g,*]

[a] *Department of Emergency Medicine, Kaohsiung Municipal Ta-Tung Hospital, Kaohsiung, Taiwan, ROC*
[b] *Department of Emergency Medicine, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan, ROC*
[c] *Department of Surgery, Faculty of Medicine, School of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan, ROC*
[d] *Department of Nursery, Kaohsiung Municipal Ta-Tung Hospital, Kaohsiung, Taiwan, ROC*
[e] *Graduate Institute of Healthcare Administration and Medical Informatics, Kaohsiung Medical University, Kaohsiung, Taiwan, ROC*
[f] *Department of Anesthesiology, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan, ROC*
[g] *Department of Anesthesiology, Faculty of Medicine, School of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan, ROC*

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Abstract

Background: To increase the chance of restoring spontaneous circulation, cardiopulmonary resuscitation (CPR) with high-quality chest compressions is needed. We hypothesized that, in a municipal hospital emergency department, the outcome in nontraumatic out-of-hospital cardiac arrest patients treated with standard CPR followed by mechanical chest compression (MeCC) was not inferior to that followed by manual chest compression (MaCC). The purposes of the study were to test our hypothesis and investigate whether the use of MeCC decreased human power demands for CPR.

Methods: A total of 455 consecutive out-of-hospital cardiac arrest patients of presumed cardiac etiology were divided into two groups according to the chest compressions they received (MaCC or MeCC) in this retrospective review study. Human power demand for CPR was described according to the Basic Life Support/Advanced Cardiovascular Life Support guidelines and the device handbook. The primary endpoint was recovery of spontaneous circulation during resuscitation, and the secondary endpoints were survival to hospital admission and medical human power demands.

Results: In this study, recovery of spontaneous circulation was achieved in 33.3% of patients in the MeCC group and in 27.1% in the MaCC group ($p = 0.154$), and the percentages of patients who survived hospitalization were 22.2% and 17.6%, respectively ($p = 0.229$). A ratio of 2:4 for the human power demand for CPR between the groups was found. Independent predictors of survival to hospitalization were ventricular fibrillation/pulseless ventricular tachycardia as initial rhythm and recovery of spontaneous circulation.

Conclusion: No difference was found in early survival between standard CPR performed with MeCC and that performed with MaCC. However, the use of the MeCC device appears to promote staff availability without waiving patient care in the human power-demanding emergency departments of Taiwan hospitals.

Keywords: cardiac arrest; cardiopulmonary resuscitation; emergency department crowding; mechanical chest compression

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Kuang-I Cheng, Department of Anesthesiology, Kaohsiung Medical University Hospital, 100, Tzyou 1st Road, Kaohsiung 807, Taiwan, ROC.

E-mail address: kuaich@kmu.edu.tw (K.-I. Cheng).

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1. Introduction

Cardiopulmonary resuscitation (CPR) using high-quality chest compressions is required in order to improve the chance of restoring spontaneous circulation.[1−3] Several studies have demonstrated that manual chest compressions (MaCCs) result in approximately 20−30% of normal cardiac output, and their effectiveness is limited because of numerous reasons, including the rescuers' endurance.[4−6] Fatigue occurs within 2−3 minutes after the start of CPR and reduces the effect of chest compressions for a few minutes before the rescuer feels exhausted.[4,7] Chest compressions are thus delivered for only half of the time, and most are very shallow during out-of-hospital cardiac arrest (OHCA).[4,8]

In Taiwan, health care is provided under the reimbursement systems of the National Health Insurance to ensure decreased economic hindrances to health care access. Emergency departments (EDs) then become overcrowded, indicating overuse, which leads to huge challenges such as an increase of patient number, and disease severity and complexity. Facing a high demand for timely treatment, emergency physicians actually practice under tremendous workload and pressure. When an OHCA patient is sent to the ED, a CPR team (at least 4 medical professionals, according to the Basic Life Support and Advanced Cardiovascular Life Support guidelines[9,10]) begins rescue efforts immediately, presenting an obvious delay to offering timely treatment to other patients. MeCC, which needs two medical professionals at the most, one to instruct and the other to install the mechanical chest compression (MeCC) device, offer treatment, and record data, was introduced in recent years, but the outcomes of cardiac arrest studies vary. Additionally, whether the use of MeCC reduces human power for CPR is of interest because it would indicate whether the staff power is sufficient to support other functions in the ED. We conducted this retrospective study to preliminarily evaluate the MeCC device prior to a larger clinical study.

The purposes of the study were to describe the outcome during a limited period in the emergence room (ER) in non-traumatic OHCA patients treated with standard CPR followed by MeCC or MaCC in a municipal hospital ED of Kaohsiung, Taiwan, and to investigate if the use of MeCC decreased human power demands for CPR without compromising patient care in the human power-demanding EDs.

2. Methods

This retrospective study conducted at the ED of one medical university-affiliated municipal hospital was approved by the hospital's institutional review board. During a period of 4 years (April 2010−December 2013), patients with OHCA of presumed cardiac etiology were enrolled. This period was divided into two parts according to the use of MeCC (May 2012−December 2013) with standard CPR or MaCC (April 2010−April 2012). Exclusion criteria included age under 18 years, trauma, pregnancy, hypothermia, intoxication, hanging and drowning, return of spontaneous circulation (ROSC) prior to arrival at the ED, and other reasons, such as terminal illness. An MeCC device (Life-Stat 1008 Cardiopulmonary Resuscitator; Michigan Instruments, Inc., Michigan, USA) was introduced to the ED of our hospital in April 2012. Prior to that, chest compressions were delivered manually only for all OHCA patients. These patients (in the MaCC group) were therefore used as a control group.

Situated in South Taiwan, Kaohsiung is second in size only to the capital Taipei in the north. The emergency medical services (EMS) system in Kaohsiung serves about 2.7 million inhabitants in an area of 3000 km^2. Ambulances are dispatched for each call judged to relate to a life-threatening state of health. All OHCA patients are treated according to the American Heart Association and the International Liaison Committee on Resuscitation guidelines, such as Basic Life Support and/or Advanced Cardiovascular Life Support guidelines.[9,10] Accordingly, when an OHCA patient was sent to the ED, at least four medical professionals were needed, including one for MeCC, one for respiratory support (Ambu CPR Pal; Ambu Corporate, Ballerup, Denmark), one for recording and prompt treatment, and one for instruction.

All data were collected from the ED of our hospital and were confirmed by the data obtained from the EMS dispatch notes. Further medical data of patients admitted alive to the hospital were collected from hospital records. The primary endpoint of the study was ROSC following resuscitation and treatment, while the secondary endpoints were survival to hospital admission and medical human power demands for CPR.

The distribution of variables is given as mean ± standard deviation and percentages. For comparison of continuous variables between groups, Student t test was used. For comparison between groups of dichotomous variables, Fisher's exact test was used. In the multivariate analyses, logistic regression was used. A p value < 0.05 was regarded as significant.

3. Results

During a period of 45 months, 455 patients who suffered from OHCA were enrolled in this study. Among these patients, 51 patients who met various exclusion criteria were excluded. The most frequent exclusion criterion was ROSC (12 cases) prior to arrival at ED. As a result, 404 patients were evaluated (216 in the MeCC group and 188 in the control group).

The patients were relatively old (mean age of 66.33 years and 64.59 years in the MeCC and the control groups, respectively), and almost two-thirds were male. About half of the patients had a history of coronary artery disease, and approximately one-third had a history of heart failure, pulmonary disease, and diabetes. There were no differences in terms of age, sex, or underlying diseases. No significant differences were also found between groups with respect to the time needed to transport the patients to the ED and first recorded electrocardiogram rhythm (Table 1). Regarding the delay resulting from calling the EMS to transport the patients to the ED, the greatest proportion of patients were sent to our

Table 1
Demographic data of patients.

	MeCC group, *n* (%)	MaCC group, *n* (%)	*p*
	216 (53.5)	188 (46.5)	
Age (y)	66.33 ± 18.57	64.59 ± 17.38	0.310
Sex (male)	133 (61.6)	120 (63.8)	0.659
Previous history [a]			
Coronary artery disease	110 (50.9)	92 (48.9)	0.387
Heart failure	52 (24.1)	56 (29.8)	0.506
Pulmonary disease	44 (20.3)	32 (17.0)	0.578
Diabetes	35 (16.2)	32 (17.0)	0.583
Others	60 (27.8)	55 (29.3)	0.452
Arrived ER in 10 min	149 (69.0)	133 (70.7)	0.676
VF/Pulseless VT as initial rhythm	18 (8.3)	13 (6.9)	0.597

Data are presented as *n* (%) or mean ± SD.
ER = emergency room; MaCC = manual chest compressions; MeCC = mechanical chest compressions; SD = standard deviation; VF = ventricular fibrillation; VT = ventricular tachycardia.
[a] Information was frequently missed. Not all the previous histories of the patients were obtained.

ED within 10 minutes for both groups (69.0% vs. 70.7%, $p = 0.676$). The proportion of patients found in ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT) was not significantly different between groups as well (8.3% vs. 6.9%, $p = 0.597$).

As shown in Table 2, both ROSC (33.3% vs. 27.1%, $p = 0.154$) and the number of patients who survived hospitalization (22.2% vs. 17.6%, $p = 0.229$) increased after MeCC was used with standard CPR at the ED, however without significant differences.

Several factors were simultaneously considered to find independent predictors of survival to hospitalization. The factors included age, sex, previous medical history, arrival at ER within 10 minutes, initial rhythm (VF/pulseless VT), MeCC/MaCC, and ROSC. Independent predictors of survival to hospitalization are listed, in order of significance, in Table 3. The chance of survival to hospitalization increased 4.37 times if the patients had VF/pulseless VT as the initial rhythm and approximately 468 times if they had ROSC. Age, sex, previous medical history, arrival at ER within 10 minutes, and MeCC/MaCC were not found to be independent predictors of survival to hospitalization in the present analysis.

When an OHCA patient was sent to the ED, at least four medical professionals were needed when there was no MeCC device—one for MeCC, one for respiratory support (Ambu), one for prompt treatment and medical recording, and one for instruction. As fatigue occurred soon after the start of CPR, these four persons took turns performing MeCCs every 2 minutes during the minimum request of 30 minutes of CPR suggested by the Advanced Cardiovascular Life Support guideline. However, when the MeCC device was introduced, only two medical professionals were needed to instruct, keeping records, and offer treatments. The MeCC device performed chest compressions without fatigue and provided respiratory support. This resulted in a ratio of 2:4 for the human power demand for CPR between the MeCC group and MaCC group.

Table 2
Study endpoints.

	MeCC group, *n* (%)	MaCC group, *n* (%)	*p*
	216 (53.5)	188 (46.5)	
ROSC	72 (33.3)	51 (27.1)	0.154
Survival to hospitalization	48 (22.2)	33 (17.6)	0.229

Data are presented as *n* (%) or mean ± SD.
MaCC = manual chest compressions; MeCC = mechanical chest compressions; ROSC = recovery of spontaneous circulation.

Table 3
Independent predictors of survival to hospitalization.

	SE	Odds ratio	95% CI	*p*
Initial rhythm [a]	0.569	4.37	1.43–13.32	0.010
ROSC [b]	1.022	468.08	63.20–3466.72	< 0.001

CI = confidence interval; ROSC = recovery of spontaneous circulation; SE = standard error; VF = ventricular fibrillation; VT = ventricular tachycardia.
[a] VF/pulseless VT as initial rhythm: Yes/no.
[b] Yes/no.

4. Discussion

In this study, there was no difference in the early survival after OHCA between patients treated with MeCC and those treated with MaCC. However, several factors might explain the survival to hospitalization that was observed.

During May 2012–December 2013, 216 OHCA patients received MeCC. In this group, we found relatively older patients, fewer women, and the higher rate of survival to hospitalization.

Recent studies reveal a survival-to-hospitalization rate of 21–25% after OHCA and a larger proportion (38%) of patients who survived hospitalization if the study sample included only those experiencing cardiac arrests.[1,4] As presented in our study, 22.2% of the patients in the MeCC group and 17.6% in the MaCC group survived to hospitalization, though significant difference was not found. However, they were somewhat in accordance with the results of the above-mentioned studies.

The chance of survival to hospitalization was slightly higher when the patients received MeCC. It is only possible to speculate about the reasons for those findings. The prehospital protocol of CPR begins with MaCC and defibrillation when possible. If the patient does not receive ROSC upon arrival at the ED, the next step at the ED is to apply the mechanical device and subsequently begin intubation and intravenous treatments. All survivors had received ROSC after MeCC was used.

Whether MeCC improved the outcome after OHCA was not confirmed in our study. Several studies have also concluded insufficient delivery of MeCC in both quality and quantity.[1,5,8] However, the performance of MaCC faces additional challenges, such as poor production of cardiac output and rescuer fatigue. In addition, ED crowding, one of the big issues

needing a prompt solution, might be caused by several seasons such as an increasing volume of critically ill patients presenting to EDs and a lack of available intensive care unit beds.[11,12] As a result of ED crowding, staff availability might be reduced, ancillary services such as radiology and laboratory results impeded, and the care quality debased.[13−16] In this study, we found that only one medical professional was needed for keeping medical records and prompt treatment after the introduction of the MeCC device, indicating a 75% reduction in human power demand. The MeCC device is, therefore, an alternative to human power under such a demanding circumstance in the ED, since the outcome of MeCC after OHCA was not inferior to that of MaCC.

With regard to the patient characteristics, i.e., age, sex, previous medical history, and arrival at ER within 10 minutes, there were no unexpected findings. People in a better-educated society appear to call the EMS sooner.[17] OHCA patients then have a chance to be sent to the EDs without delay. However, we did not find that arrival at ER within 10 minutes was an independent predictor of survival to hospitalization in the study.

With the passage of every minute after a cardiac arrest, VFs have increasingly converted to nonshockable rhythms,[17] explaining the finding of a relatively low percentage of patients with VF and pulseless VT. The low percentage of patients with VF and pulseless VT found in the study was in agreement with many studies.[18,19] Several studies revealed that most OHCA patients who survived the prehospital phase were patients with VF and VT.[1,20] This agrees to some degree with the present multivariate analyses showing that VF/pulse VT was a strong independent predictor of survival to hospitalization.

This study has several limitations. The study site was an urban university-affiliated ED. The study's single-center retrospective study design might limit its generalizability. In addition, the quality of CPR was not measured and evaluated in the study. A large-scale, well-designed prospective study is needed to better test the outcomes of MeCC for OHCA patients in an ED.

In conclusion, in this study of nontraumatic OHCA patients, we found no difference in early survival between standard CPR performed with MeCC and that performed with MaCC. With regard to MeCC, there are benefits for the working environment of ED, although our conclusion is unable to assert that MeCC contributed to the increase in survival to hospitalization. However, the use of the MeCC device appears to promote staff availability without waiving patient care in the human power-demanding EDs of Taiwan hospitals.

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