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Original Article

Manual cardiopulmonary resuscitation versus mechanical cardiopulmonary resuscitation: Which one is more effective during ambulance transport?

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Abstract:

OBJECTIVES: Although studies in the field of emergency medical services (EMS) generally compare survival and hospital discharge rates, there are not many studies measuring the quality of cardiopulmonary resuscitation (CPR). In this study, we aimed to compare the mechanical chest compression device and paramedics in terms of CPR quality.

METHODS: This is an experimental trial. This study was performed by the EMS of Ankara city (capital of Turkey). Twenty (ten males and ten females) paramedics participated in the study. We used LUCAS™ 2 as a mechanical chest compression device in the study. Paramedics applied chest compression in twenty rounds, whereas mechanical chest compression device applied chest compression in another set of twenty rounds. The depth, rate, and hands-off time of chest compression were measured by means of the model's recording system.

RESULTS: The median chest compression rate was 120.1 compressions per minute (interquartile range [IQR]: 25%–75% = 117.9–133.5) for the paramedics, whereas it was 102.3 compressions per minute for the mechanical chest compression device (IQR: 25%–75% = 102.1–102.7) ($P < 0.001$). The median chest compression depth was 38.9 mm (IQR: 25%–75% = 32.9–45.5) for the paramedics, whereas it was 52.7 mm for the mechanical chest compression device (IQR: 25%–75% = 51.8–55.0) ($P < 0.001$). The median hands-off time during CPR was 6.9% (IQR: 25–75 = 5.0%–10.1%) for the paramedics and 9% for the mechanical chest compression device (IQR: 25%–75% = 8.2%–12.5%) ($P = 0.09$).

CONCLUSION: During patient transport, according to the chest compression performed by the health-care professionals, it was found that those performed by the mechanical chest compression device were more suitable than that performed by the guides in terms of both speed and duration.

Keywords:

Cardiopulmonary resuscitation quality, mechanical chest compression devices, prehospital, resuscitation

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Box-ED Section

What is already known on the study topic?

Because the ambulance is mobile during the transport process, the depth and rate of chest compressions cannot be provided in accordance with the values specified in the guidelines.

What is the conflict on the issue? Has its importance for readers?

The most important step of survival in cardiopulmonary resuscitation (CPR) is the quality of chest compressions. In this study, the difference in chest pressure between the paramedics and the mechanical chest compression device was investigated in prehospital arrest patients.

How is this study structured?

This study was performed experimentally by the emergency medical services of Ankara city.

What does this study tell us?

During the ambulance transfer of cardiac arrest patients, mechanical chest compression devices and paramedics were compared according to their accuracy to CPR guidelines in terms of chest compression speed, depth, and hands-off time.

Introduction

High-quality chest compression (HQCC) is very important for survival in cardiopulmonary arrest patients.^[1] To administer HQCC, the thoracic cage must be fully loosened between compressions at sufficient depth and speed.^[2] It is quite difficult to administer HQCC during the prehospital period; the skill level or the number of staff may be inadequate, the staff may be tired, there may be scene-related or patient-related problems (e.g., chest elasticity differences and vascular difficulties), and it may be difficult to apply chest compressions in a moving ambulance. Although survival is very low after prehospital cardiac arrest,^[3] the effective implementation of life chain steps can increase survival by up to 50%.^[2]

Mechanical chest compression devices (MCCD) are designed to provide chest compressions at an appropriate depth and frequency without causing fatigue.^[4] According to studies on the prehospital period, there is no difference between manual cardiopulmonary resuscitation (CPR) and MCCD-administered CPR in terms of hospital discharge and 30-day survival rates.^[5,6]

Although there are studies on the prehospital period comparing the survival and hospital discharge rates achieved after manual CPR versus MCCD-administered CPR, there are not many studies that measure the quality of CPR during this period. The main problem with prehospital cardiac arrest cases is the transport of the patient to the hospital. Sudden braking or acceleration of the ambulance and a decrease in CPR efficiency as

the ambulance travels through road bends are important challenges. These challenges experienced by health-care professionals during transport cause pauses in the CPR.^[7] Administering CPR during ambulance transports also endangers the safety of health-care professionals.

In this study, we aimed to evaluate and compare the qualities of chest compressions performed manually by health-care professionals and by a MCCD on a training model during a mode of ambulance transport.

Methods

This study was performed experimentally by the emergency medical services (EMS) of Ankara city (the capital of Turkey). Ethics committee approval of the study was obtained from the University of Health Sciences, Turkey. Non-interventional Research Ethical Committee, University of Health Sciences, Date: 16.10.2018, Approval number: 18/218).

Characteristics of the participants

Twenty paramedics – each of which had at least 5 years of field experience in the EMS of Ankara city and had completed the four training modules of the Ministry of Health (MoH) of the Republic of Turkey – were included in this study on a voluntary basis. The paramedic participants were allowed to get used to the training model by practicing on it for 10 min before the study. The participants were asked to apply chest compressions to the training model (in accordance with the 2015 American Heart Association guidelines) within the moving ambulance. All safety measures were taken to prevent the paramedic participants from skidding, falling, or being injured while administering chest compressions [Figure 1].

Characteristics of the ambulance driving track

The points where paramedics would have difficulty to perform CPR in the ambulance had been preevaluated. To prevent these difficulties in advance, a driving track for ambulance driving training was simulated in accordance with the national standards of the MoH of Turkey and the actual conditions. The driving track is designed to help drivers practice evasive maneuvering, parking, slalom, swiveling, and panic braking. The width of the driving track was 1.5 m, and its total length was 269 m [Figure 2].

The study was originally intended to be carried out on a city traffic route instead of a simulated driving track. However, because the volume of traffic could not be standardized, it was finally decided to carry out the study on this driving track.

Characteristics of the ambulance

In this study, a fully equipped training



Figure 1: Application of chest compressions to the training model in an ambulance by paramedics and the safety measures taken

ambulance (Mercedes Sprinter®, 2015, Germany) from the EMS of Ankara city was used. To ensure standardization, the ambulance was driven by the same ambulance driving trainer each time. Before the start, the driver was allowed to take five practice laps to get used to the driving track. During the study, the drivers were asked to go as fast as they could, but they reached a maximum speed of 40 km/h to ensure ambulance paramedics safety. The speed was up to 40 km/h on the straight-ahead route, while the maximum speed was 20 km/h in the maneuvering areas.

Characteristics of the cardiopulmonary resuscitation training model

The Simian 3 training model (Laerdal®, Stavanger, Norway 2014) was used to measure the speed of the chest compressions and the duration of the interruptions between them, which are indicators of CPR quality. While the ambulance was driven on the track, the paramedic or the MCCD performed chest compressions on the model. The MCCD was fixed to the model by using belts to prevent it from sliding over the model. The model was fixed to the ambulance stretcher by a three-point climbing belt to prevent the model from sliding. Chest compressions were started immediately when the ambulance began to move. The training model recorded the chest compression rate (number of compressions per minute), compression depth, and hands-off time (hands-off time describes the interruptions that occur during chest compression).

The LUCAS™ Chest Compression System (Lund University Cardiopulmonary Assist System; Physio-Control Inc./Jolife AB, Lund, Sweden) was used as the MCCD. The MCCD was fixed to the manikin by fastening the belts. The chest compression rate of the MCCD was set to 100/min, while its compression depth was set to 5 cm.

Application

In the first stage, the paramedic participants performed

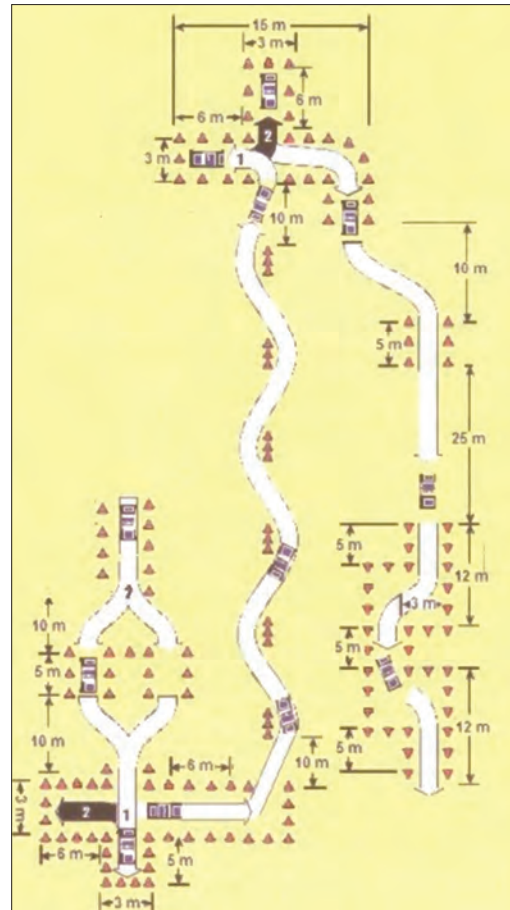


Figure 2: Ambulance-driving training track of the city of Ankara, Ministry of Health, in the Republic of Turkey. *m: Meter

manual chest compressions on the model while the ambulance was moving. To assess the effectiveness of the paramedics, each of the twenty paramedics took two laps around the track (20 paramedics × 2 laps = 40 laps). Because the ambulance did not move straight and maneuvered continuously, it was thought that one round would not be enough to assess the effectiveness of each paramedic. One lap of the ambulance around the track took an average of 2 min (a total of 80 min).

In the second stage, in order to ensure the equal time and CPR conditions with paramedics, forty more laps were driven performing chest compressions with the MCCD. To make comparisons with paramedics, at the end of each two laps, the number of chest compressions, the depth of compressions, and hands-off time were recorded; the CPR process and ambulance movements were recorded by cameras placed in the front and rear cabins of the ambulance.

Statistical analysis

All data recorded during the study were analyzed using SPSS software. The company information for the version 15.0 is as follows: SPSS for Windows, Version 15.0. Chicago, SPSS Inc. Categorical data were expressed as

frequencies and percentages. The Kolmogorov–Smirnov test was used to determine whether the continuous data had a normal distribution. While the variables that were normally distributed were expressed as means and standard deviations, the variables that were not normally distributed were expressed as medians and 25–75 quarters. Student's *t*-test was used for parametric data, whereas the Mann–Whitney U-test was used for nonparametric data. To determine the statistical significance level, the critical alpha value was defined as $P < 0.05$.

Results

A total of twenty paramedics (ten males and ten females) were included in the study. The average number of years of experience for the paramedics was 7.65. The median age was 25.5 years (24–30) and the median body mass index was 23.1 kg/m² (20.8–25.8) [Table 1].

In this study, the median chest compression rate was 120.1 compressions per minute (117.9–133.5) for the paramedics, whereas it was 102.3 compressions per minute for the MCCD (102.1–102.7). There was a statistically significant difference between the study groups in terms of chest compression rate ($P < 0.001$) [Table 2].

The median chest compression depth was 38.9 mm (32.9–45.5) for the paramedics, whereas it was 52.7 mm for the MCCD (51.8–55.0). There was a statistically significant difference between the study groups in terms of chest compression depth ($P < 0.001$) [Table 2].

The median hands-off time during CPR was 6.9% (5.0%–10.1%) for the paramedics and 9% (8.2%–12.5%) for the MCCD. There was no statistically significant difference between the study groups in terms of hands-off time during CPR ($P = 0.09$) [Table 2].

It was found that MCCD performed more appropriate CPR in terms of speed and depth than female paramedics, but there was no statistical difference between the two in terms of hands-off time. When MCCD and male paramedics were compared, MCCD performed more appropriate CPR in terms of chest compression speed and depth, and male paramedics had less hands-off time than MCCD [Table 3].

Discussion

Cardiac arrest patients should be treated as soon as possible. Performing high-quality CPR at the scene and during transport is very important for these patients. Although it is relatively easy to administer CPR at the scene, it is quite difficult to administer CPR in a moving ambulance during transport. The sudden

Table 1: Descriptive characteristics of the participant paramedics

Characteristics	Median	IQR 25%–75%
Age	25.5 years	24–30
BMI	23.1	20.8–25.8
Height	168.0 cm	161.2–177.5
Weight	67.0 kg	55.0–81.5

BMI: Body mass index, IQR: Interquartile range

Table 2: Chest compression rate, compression depth, and hands-off time findings*

	MCCD	Paramedics	P
Speed	102.3 compressions per min (102.1–102.7)	120.1 compressions per minute (117.9–133.5)	<0.001
Depth	52.7 mm (51.8–55.0)	38.9 mm (32.9–45.5)	<0.001
Hands-off time	9% (8.2%–12.5%)	6.9% (5.0%–10.1%)	0.09

*Values are defined as IQR and as median. IQR: Interquartile range, MCCD: Mechanical chest compression device

accelerations, decelerations, and centrifugal forces in moving ambulances are the factors that make it difficult for paramedics to perform CPR. In order to avoid these factors, the use of MCCDs in prehospital emergency medical systems was investigated, and there was no statistically significant difference in the patient survival rates attained after manual CPR applications and MCCD use.^[1,5,6] However, there are not many studies that examine CPR quality during the prehospital period. Therefore, in this study, we evaluated the effect of MCCD use on CPR quality in EMS. In our study, we found that the use of MCCD in patients with cardiac arrest in EMS was more effective when compared with paramedics in terms of chest compression rate and depth during CPR. We did not find a significant difference between the two groups in terms of hands-off time.

The current adult cardiac life support guidelines recommend 100–120 chest compressions per minute. It has been shown that a rate faster than 120 compressions per minute reduces the compression depth and therefore reduces venous return to the heart, coronary perfusion pressure, and myocardial blood supply. In our study, the compression speed of the paramedics was at the upper limits indicated in the CPR guidelines, whereas the compression speed of the MCCD was within the specified range. According to a study investigating CPR quality during patient transport by helicopter, the median compression rate was reported as 100 ± 0.5 compressions per minute for MCCD and 113 ± 6 compressions per minute for paramedics.^[8] In the aforementioned study, the manual compression rate may have been in the targeted range because helicopters provide a more stable setting than land ambulances, and sudden movements are less frequent in helicopters. In another study conducted in Denmark, chest compressions of MCCDs and paramedics while transferring patients to hospitals

Table 3: Chest compression rate, depth, and hands-off time according to paramedic participant gender groups*

	MCCD	Female paramedics	Male paramedics	P1 value	P2 value	P3 value
Speed	102.3 compressions per min (102.1–102.7)	119.2 compressions per min (108.1–121.7)	133.1 compressions per min (119.7–141.5)	<0.001	<0.001	0.015
Depth	52.7 mm (51.8–55.0)	36.4 mm (32.0–39.3)	43.7 mm (33.9–47.4)	<0.001	<0.001	0.14
Hands-off time	9% (8.2%–12.5%)	9.2% (5.2%–11.1%)	5.5% (0%–8.5%)	0.775	0.016	0.24

*Values are defined as IQR and median. P1: Comparison of MCCD versus female paramedics, P2: Comparison of MCCD versus male paramedics, P3: Comparison of male and female paramedics. IQR: Interquartile range, MCCD: Mechanical chest compression device

were compared. It was determined that MCCDs applied chest compressions at the rate specified in guidelines, whereas paramedics performed chest compressions faster than that recommended by guidelines.^[9] We think that the reason why paramedics perform chest compressions faster in mobile environments is that they protect themselves from the effect of skidding by making more contact with the patient during compression.

We found that the compression depth achieved by the paramedics was lower than that achieved by the MCCD. According to a study by Yuksen *et al.*, there was no difference between the depth of the CPR compressions obtained in a stable setting by MCCD and that obtained by a health-care professional.^[10] Similar to our study, Fox *et al.* found that paramedics performed the appropriate chest compression depth by 67%.^[11] In two different studies, the compression application difference between EMS professionals and two different automated-CPR devices was evaluated, and the compression depth provided by the automated-CPR devices was found to be more appropriate than those of paramedics.^[12,13] We believe that the paramedics achieved a lower depth of compression because the ambulance is not a stable environment. The driving track of our study included harsh conditions that required These maneuvers are taught by the Ministry of Health of Turkey in in-service training and overlap with the conditions of the EMS field. and the paramedics were jarred by skidding in the ambulance. In our study, faster chest compressions performed by the paramedics may have caused a decrease in depth. As stated in the literature, faster chest compressions cause a decrease in compression depth.

In a study by Olasveengen *et al.* comparing MCCD with manual CPR during transport, MCCD's hands-off time was found to be 8% of the entire CPR process, while it was 27% in paramedics.^[14] In another study, while the hands-off time was 8.6 s during manual CPR, MCCD (LUCAS-2) performed uninterrupted CPR.^[15] In our study, no significant difference was found between the paramedics and the MCCD in terms of hands-off time. Although we fixed the MCCD to the model, it slipped over the model during the movement and lost its position, which could be the reason of no difference found.

In the literature, no significant difference was found between MCCD-administered CPR and manual CPR in

terms of survival and neurological damage.^[4-6,16-18] Survival results have been demonstrated in large randomized clinical trials; however, the effect of CPR quality on patient outcome is not discussed. It is emphasized that CPR quality is the most important factor affecting survival. However, there are not many studies in the literature that compare the quality of CPR achieved by MCCD and that achieved by health-care professionals. We believe that our study is important because it demonstrates that the quality of MCCD-administered CPR during ambulance transports is better than that of manual CPR.

We found that MCCD was more effective than male or female paramedics at chest compression rate and depth. In addition, we found that there was no difference between MCCD and female paramedics according to hands-off time. However, male paramedics had less hands-off time. This may be due to the fact that the MCCD has slipped over the mannequin, especially during the maneuver.

Limitations

The most important limitations of our study are the number of manual CPR samples, the duration of CPR administration, and the maximum speed of the ambulance. Our study was carried out on a driving track, not in real city traffic during a real patient transport (so as not to endanger the safety of any drivers, pedestrians, or health-care professionals). However, it is certain that the ambulance will be faster and less controlled during real hospital transport, a factor that may make MCCD-administered CPR a better choice.

Conclusion

During patient transport, according to the chest compression performed by the health-care professionals, it was found that those performed by the mechanical chest compression device were more suitable than that performed by the guides in terms of both speed and duration.

Author contributions statement

Burak Bekgöz conceived the study and designed the trial. İshak Şan gathered and analyzed the data. Mehmet Ergin and Eren Usul drafted the manuscript, and all authors contributed substantially to its revision.

Conflicts of interest

None Declared.

Ethical approval

Ethical approval for this study was obtained from the Non-Interventional Research Ethics Committee, University of Health Sciences (approval number 18/218, Date: 16.10.2018).

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