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Comparison of chest compressions with and without LUCAS3 mechanical chest compression system during resuscitation performed by novice physicians

Porównanie kompresji klatki piersiowej z systemem i bez systemu mechanicznej kompresji klatki piersiowej LUCAS3 podczas resuscytacji wykonywanej przez lekarzy stażystów

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Keywords

cardiopulmonary resuscitation, quality, chest compression, physician, medical simulation

Słowa kluczowe

resuscytacja krążeniowo-oddechowa, jakość, kompresja klatki piersiowej, lekarz, symulacja medyczna

S u m m a r y

Introduction. High quality chest compression is one of the basic elements influencing the effectiveness of cardiopulmonary resuscitation and thus the return of spontaneous circulation. In the case of prolonged resuscitation or when the resuscitation is carried out by one person, the quality of chest compressions may decrease. Mechanical chest compression systems may be helpful.

Aim. The aim of the study was to compare the quality of manual chest compression and mechanical chest compression system LUCAS3 during simulated cardiopulmonary resuscitation conducted by novice physicians.

Material and methods. The study was designed as a prospective, randomized, cross-over simulation study. The study involved 36 novice physicians to perform chest compressions with and without the LUCAS3 chest compression system. The participants performed chest compressions continuously.

The study protocol was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (Approval no.: 32.05.2017.IRB).

Results. The depth of chest compressions measured in the second minute of resuscitation with and without LUCAS3 was 52 (IQR: 51-53) and 51 (IQR: 45-53) mm, respectively, with chest compression rates of 110 (IQR: 105.2-115.2) and 127 (IQR: 102-133) compressions per minute. For manual chest compressions, incomplete chest recoil was 15 (IQR: 8-21)% and for LUCAS3 0 (IQR: 0-1)%. From 4, through 6 and 8 minutes of resuscitation, LUCAS3 chest compressions were statistically significantly better ($p < 0.05$) compared to manual chest compressions for all analyzed chest compression parameters (depth and rate of chest compression; degree of chest recoil and point of chest compression).

Conclusions. In a simulation study, novice physicians using the LUCAS3 chest compression system performed higher quality chest compressions than manual chest compressions. With prolonged resuscitation, the quality of manual chest compressions decreases significantly.

S t r e s z c z e n i e

Wstęp. Wysokiej jakości kompresja klatki piersiowej to jeden z podstawowych elementów wpływających na skuteczność resuscytacji krążeniowo-oddechowej, a tym samym powrót spontanicznego krążenia. W przypadku przedłużającej się resuscytacji bądź gdy prowadzona jest ona przez jedną osobę, jakość kompresji klatki piersiowej może ulec zmniejszeniu. Wówczas pomocne mogą okazać się systemy mechanicznej kompresji klatki piersiowej.

Cel pracy. Celem pracy było porównanie jakości kompresji klatki piersiowej wykonywanej manualnie oraz z zastosowaniem mechanicznego systemu kompresji klatki piersiowej LUCAS3 podczas symulowanej resuscytacji krążeniowo-oddechowej prowadzonej przez lekarzy stażystów.

Conflict of interest
Konflikt interesów

None
Brak konfliktu interesów

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Materiał i metody. Badanie zaprojektowano jako prospektywne, randomizowane, krzyżowe badanie symulacyjne. W badaniu udział wzięło 36 lekarzy stażystów, którzy mieli za zadanie wykonywanie uciśnięć klatki piersiowej z systemem i bez systemu kompresji klatki piersiowej LUCAS3. Uczestnicy wykonywali uciśnięcia klatki piersiowej w sposób ciągły.

Protokół nadania został zaakceptowany przez Radę Programową Polskiego Towarzystwa Medycyny Katastrof.

Wyniki. Głębokość uciśnięć klatki piersiowej mierzona w 2. minucie resuscytacji z systemem i bez systemu LUCAS3 wynosiła odpowiednio 52 (IQR: 51-53) i 51 (IQR; 45-53) mm, zaś częstość kompresji klatki piersiowej wynosiła 110 (IQR: 105,2-115,2) i 127 (IQR: 102-133) uciśnięć na minutę. W przypadku manualnego uciskania klatki piersiowej niepełna relaksacja klatki piersiowej wynosiła 15 (IQR: 8-21)%, zaś w przypadku systemu LUCAS3 – 0 (IQR: 0-1)%. Poczynając od 4., poprzez 6. i 8. minutę resuscytacji, kompresja klatki piersiowej z wykorzystaniem systemu LUCAS3 w porównaniu z manualnym uciskaniem klatki piersiowej była istotnie statystycznie lepsza ($p < 0,05$) w odniesieniu do wszystkich analizowanych parametrów kompresji klatki piersiowej (głębokości i częstości kompresji klatki piersiowej, stopnia relaksacji klatki piersiowej oraz punktu ucisku klatki piersiowej).

Wnioski. W przeprowadzonym badaniu symulacyjnym lekarze stażyści, stosując system kompresji klatki piersiowej LUCAS3, wykonywali wyższej jakości kompresję klatki piersiowej aniżeli w przypadku manualnego uciskania klatki piersiowej. Wraz z wydłużeniem czasu trwania resuscytacji zmniejsza się istotnie jakość manualnej kompresji klatki piersiowej.

INTRODUCTION

Sudden cardiac arrest is a challenge for medical personnel. In order to carry out advanced resuscitation procedures, it requires professional practical skills, medical knowledge as well as logistical skills in order to optimize the resuscitation team's performance (1, 2). In United States, 225 000 to 750 000 people annually require cardiopulmonary resuscitation (CPR), and the survival to hospital discharge ranges between 5 and 20% (3).

Cardiopulmonary resuscitation is regulated by the American Heart Association (AHA) as well as the European Resuscitation Council (ERC) guidelines (4, 5). Both the depth and rate of chest compressions and the ratio of chest compressions to ventilation have been established by these societies based on Evidence Based Medicine (EBM). Current guidelines, in addition to high quality chest compressions based on the above indicators, also place an emphasis on minimizing interruptions in chest compressions.

Cardiopulmonary feedback devices or mechanical chest compression devices may be effective in the event of prolonged resuscitation or transport of a patient in cardiac arrest (6, 7). An example of such a device is the 2nd and 3rd generation mechanical chest compression system LUCAS, which are the most common chest compression systems used in Poland (fig. 1).

Fig. 1. Mechanical chest compression device LUCAS3

AIM

The aim of this study was to compare the quality of manual chest compressions and mechanical chest compression LUCAS3 during simulated cardiopulmonary resuscitation by novice physicians.

MATERIAL AND METHODS

The study was designed as an observational, randomized, cross-over simulation study. Prior to the study, the study protocol was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (Approval no.: 32.05.2017.IRB). The study was carried out on 36 novice physicians taking part in emergency medicine course. Among the criteria excluding from the examination were: upper limb or back injuries preventing high quality chest compressions or pregnancy.

Study protocol

Prior to the survey, all study participants participated in a Basic Life Support training based on the European Resuscitation Council guidelines. At the end of the training, participants were demonstrated how to conduct chest compressions using the LUCAS3 mechanical chest compression system, and after the training, participants had a 10-minute practical training, during which they learned how to operate LUCAS3.

During the target study, participants were asked to perform continuous chest compression for 8 minutes with and without LUCAS3 chest compression device.

The compression was performed continuously for 8 minutes. The 8-minute period was accepted as the median time of the arrival of the medical rescue team in the urban agglomeration is 8 minutes. After an 8-minute resuscitation cycle, the participants had a 30-minute break and then performed the resuscitation using a different technique. A detailed randomization procedure was presented in figure 2. In order to simulate a patient with cardiac arrest, a Resusci Anne SkillReporter manikin was used (Laerdal Medical, Stavanger, Norway) which was placed on the floor level.

Measurements

Only chest compression parameters were taken into account in the analysis. CPR data were recorded by the Resusci Anne SkillReporter. The quality of chest compression was assessed using the median compression depth, median chest compression rate, proportion of chest compressions at the appropriate depth (50-60 mm), and percentage of incomplete chest recoils and percentage of incorrect hand positioning.

Statistical analysis

Data were presented as the median and interquartile range (IQR), or number and percentage (%). All analysis were performed using statistical package STATISTICA 13.3EN (TIBCO Inc., Tulusa, OK, USA). Normal distribution was confirmed using the Kolmogorov-Smirnov test. Continuous variables were compared using a parametric Student t test, or nonparametric data, the Mann-Whitney U test. A result of $p < 0.05$ was considered significant.

RESULTS

The study involved 36 novice physicians who performed cardiopulmonary resuscitation for 8 minutes with and without the LUCAS3 chest compression system.

Compression depth

The depth of compressions without and with LUCAS3 measured during the second minute of resuscitation was 51 mm (IQR: 45-53) vs. 52 mm (IQR: 51-53), respectively, but in 4, 6 and 8 minutes, the differences in chest compression depth between the chest compression techniques studied were statistically significant (fig. 3).

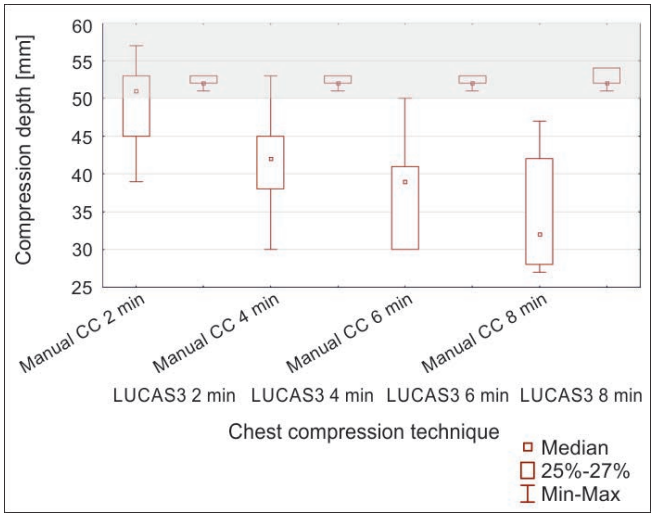

Fig. 3. The median chest compression depth

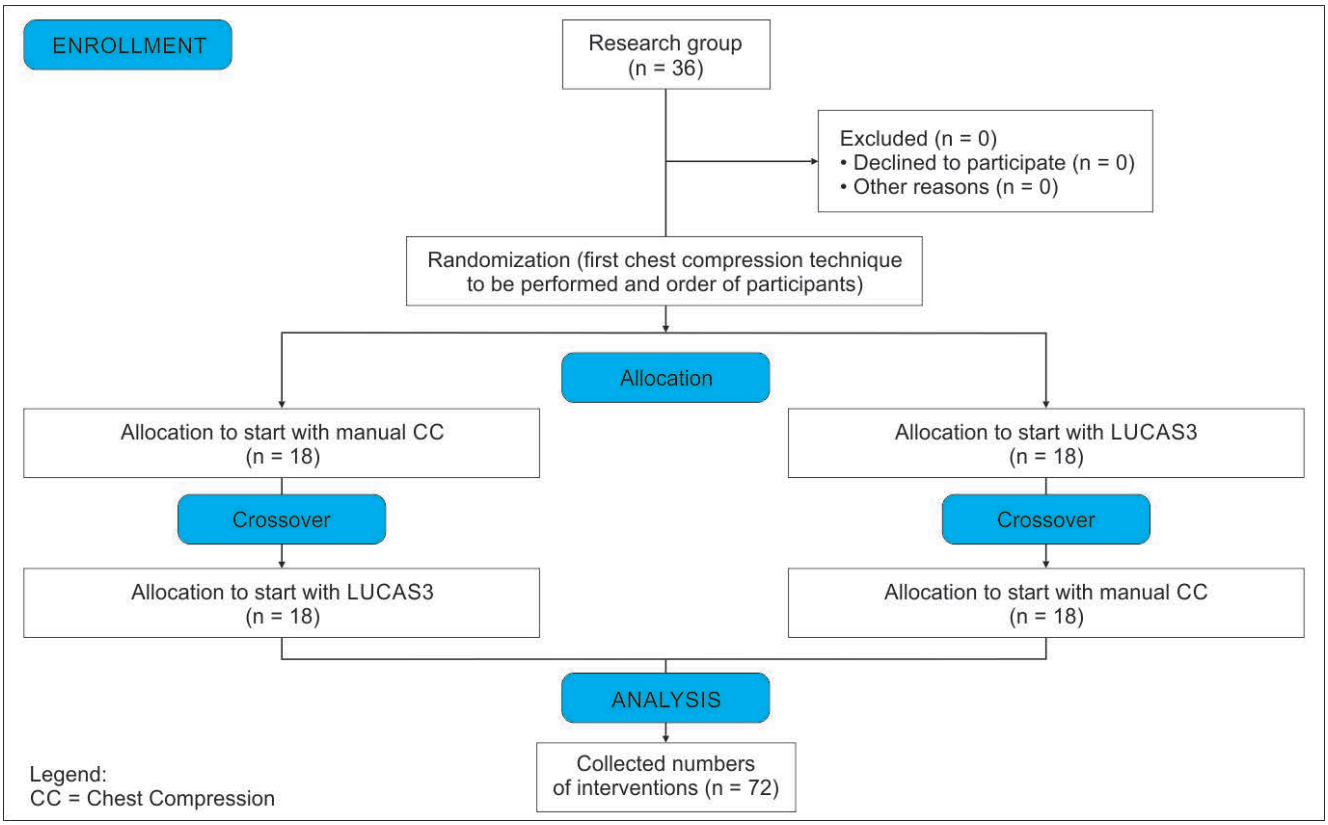

Fig. 2. The randomization flow diagram

Compression rate

The chest compression rate with and without LUCAS3 varied between minutes of resuscitation and was 2 minutes respectively: 110 vs. 127 CPM ($p = 0.032$); in 4 minutes: 110 vs. 104 CPM ($p = 0.007$); in 6 minutes: 110 vs. 93 CPM ($p < 0.001$), and in 8 minutes: 110 vs. 91 CPM ($p < 0.001$). Graphical representation of chest compression rate using two compression techniques is shown in figure 4.

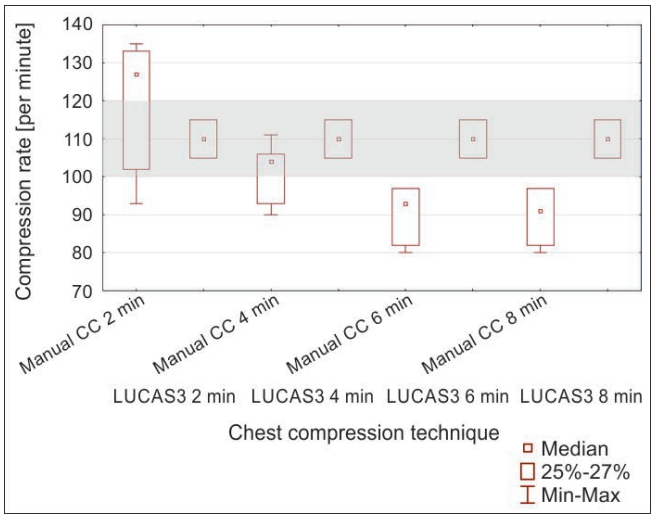

Fig. 4. The median chest compression rate

Adequate compression ratio

Chest compression using LUCAS3 showed an adequate compression ratio compared to manual compression (tab. 1). The rate of chest compression recommended by the European Resuscitation Council guidelines was considered the reference values.

Incomplete chest recoil

Incomplete chest recoils in the examined chest compression techniques showed significant statistical differences in each measurement period. A detailed comparison is presented in table 1 and figure 5.

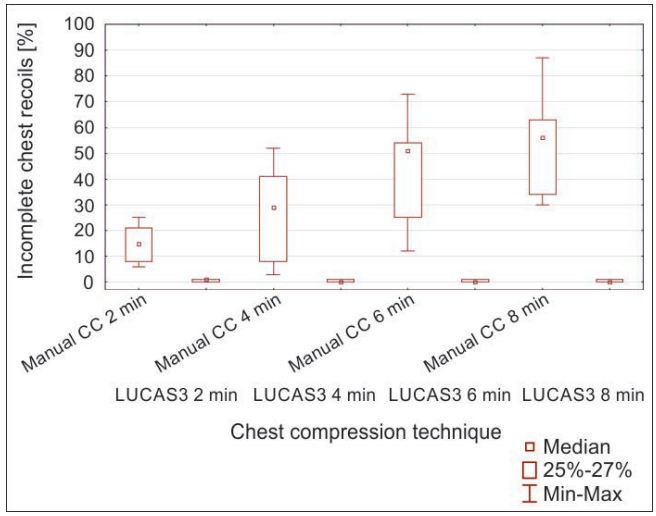

Fig. 5. The incomplete chest recoils

Incorrect hand position

Improper hand position for cardiopulmonary resuscitation with LUCAS3 was negligible and was due to incorrect piston position. With manual chest compressions, as resuscitation prolongs, there was an increase in the incorrect location of the hands on the chest. Incorrect hand positions using manual compression and LUCAS3 showed significant statistical differences in 4, 6 and 8 minutes of resuscitation ($p < 0.001$).

DISCUSSION

Medical simulation was used as a method of measuring the quality of cardiopulmonary resuscitation. The aim of the study was to perform 8-minutes of cardiopulmonary resuscitation of an adult with and

Tab. 1. Performance of cardiopulmonary resuscitation with and without LUCAS3 chest compression device

Parameter	CC technique	2 min	4 min	6 min	8 min
Compression depth (mm)	Manual CC	51 (45-53)	42 (38-45)	39 (30-41)	32 (28-42)
	LUCAS3	52 (51-53)	52.2 (51.2-53.5)	52 (51-53.3)	52.1 (51-54)
	p-value	NS	< 0.001	< 0.001	< 0.001
Compression rate	Manual CC	127 (102-133)	104 (93-106)	93 (82-97)	91 (82-97)
	LUCAS3	110 (105.2-115.2)	110 (105.2-115.2)	110 (105.2-115.2)	110 (105.2-115.2)
	p-value	0.032	0.007	< 0.001	< 0.001
Adequate compression ratio (%)	Manual CC	67 (54-83)	36 (21-54)	6 (2-7)	5 (0-9)
	LUCAS3	100 (99-100)	100 (99-100)	100 (99-100)	100 (99-100)
	p-value	< 0.001	< 0.001	< 0.001	< 0.001
Incomplete chest recoils (%)	Manual CC	15 (8-21)	29 (8-41)	51 (25-54)	56 (34-63)
	LUCAS3	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)
	p-value	< 0.001	< 0.001	< 0.001	< 0.001
Incorrect hand positions (%)	Manual CC	1 (0-5)	3 (2-8)	6 (6-13)	8 (4-19)
	LUCAS3	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)
	p-value	NS	< 0.001	< 0.001	< 0.001

NS – not statistically significant

without the use of mechanical chest compression system. The analysis of the results showed that the use of mechanical chest compression system was associated with high quality chest compressions throughout the 8-minute cardiopulmonary resuscitation procedure.

One of the key parameters influencing the quality of resuscitation as indicated by the ERC and AHA guidelines is the depth of chest compression (4, 5). The resuscitation guidelines differentiate the optimal depth of chest compression for different age groups, but for adults they recommend a depth of 50 to 60 mm. As numerous studies have shown, chest compressions is often performed too shallow (8-11). In the study, the depth of chest compressions measured in the second minute of resuscitation was 51 mm, with a significant decrease in chest compressions since 4 minutes. For LUCAS3, the chest compression depth was 52 mm throughout the whole study period. These results confirm the research published by Kurowski et al. (12). Both studies by Truszewski et al. (13) and Szarpak et al. (14) indicate that mechanical chest compression systems compress the chest to a more adequate depth than manual chest compressions. Mechanical chest compression systems can also be a good alternative to manual chest compressions when patients are transported to hospital and resuscitated on board ambulances (15-17).

The chest compression rate was also measured during the study. Resuscitation guidelines recommend chest compressions at a frequency of 100-120 compression per minute (4, 5). Mechanical chest compression systems have been pre-programmed to perform chest compressions according to the current resuscitation guidelines (18). LUCAS3 allows to perform 30 chest compressions: 2 emergency breaths or continuous compression of the chest. In the study, along with the lengthening of the time of chest compressions, the frequency of chest compressions decreased, which could be caused by the rescuer's fatigue. Numerous studies (including resuscitation guidelines) recommend that chest compression changes should be made every 2 minutes, but if the rescuer is alone, resuscitation should continue until the arrival of the ambulance, the return of spontaneous circulation in the patient, or fatigue that prevents good quality resuscitation (4). Also the study published by Field et al. (19) showed that the frequency of 100-120 CPM is the most optimal.

In addition to the depth and frequency of chest compressions, full chest recoil is an important indicator of the quality of chest compressions (20-22). The most optimal difference in chest pressure responsible for the generation of perfusion pressure is achieved by applying chest compression to an appropriate depth and then performing full chest recoil (23, 24). During the study, physicians had a tendency to perform incomplete chest recoil, which increased with the time of resuscitation. With the LUCAS3 mechanical chest compression system, the degree of full chest recoil was 100%. An additional advantage of LUCAS is the suction pad, which enables active chest decompression, which is important for patients with chest wall injuries.

One of the reasons why mechanical chest compression systems are not routinely used is the increased risk of chest injuries. However, new studies indicate that the use of LUCAS2 chest compression compared to manual chest compressions does not involve an increased percentage of chest wall injuries (25). Xanthos et al. revealed that LUCAS devise minimized the resuscitation-related trauma compared with manual chest compressions in a swine model of cardiac arrest (26).

The study has several limitations. The first limitation resulting from the type of study is the fact that the study was performed under medical simulation conditions, not in real emergency conditions. However, the choice of simulator was intentional, as it allows for full standardization of the conducted procedures without potential harm to the patient. Another limitation is to include only novice physicians in the research group, however after receiving full medical license this medical group will be relatively often confronted with the necessity of performing cardiopulmonary resuscitation. The study also has its strengths, including a randomized cross-over study or the use of one of the most modern LUCAS3 chest compression systems.

CONCLUSIONS

In a simulation study, novice physicians using LUCAS3 chest compressions performed higher quality chest compressions than manual chest compressions. With prolonged resuscitation, the quality of manual chest compressions decreases significantly. Further research is needed to confirm the results.

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