

Does the use of a chest compression system in children improve the effectiveness of chest compressions? A randomised crossover simulation pilot study

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Abstract

Background: Providing high-quality chest compressions is a key element affecting the effectiveness of cardiopulmonary resuscitation (CPR).

Aim: To evaluate the effectiveness of standard (manual) chest compressions (Standard BLS, standard basic life support) and those performed with the use of the Lifeline ARM chest compression system (ARM; Defibtech).

Methods: The study was designed as a randomised crossover study. In total, 37 nurses participated in the study. They performed a randomized 2-min asynchronous resuscitation using the Standard BLS method or the ARM system. The following parameters were measured: the total number of chest compressions, the frequency of compressions (min⁻¹), compression depth (mm), and the percentage of correctly performed chest compressions and total chest decompressions. The authors also analysed the participants' preferences concerning the use of particular CPR techniques in the clinical setting.

Results: The results obtained during the simulation study with the application of the ARM system were statistically significantly better than those with the Standard BLS method ($p < 0.05$) in the case of all analysed parameters.

Conclusions: During the simulated child resuscitation performed by the nurses, the application of the Lifeline ARM chest compression system significantly improved the effectiveness of chest compressions.

Key words: resuscitation, effectiveness, simulation, child

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INTRODUCTION

The guidelines of the European Resuscitation Council (ERC), as well as the American Heart Association, put considerable emphasis on the quality of cardiopulmonary resuscitation (CPR) [1, 2]. Both in adult and child CPR, the quality of chest compressions (CC) plays a crucial role in the survival of patients with sudden cardiac arrest (SCA).

Many studies have shown low effectiveness of CC performed by lay people without medical training [3, 4]. Research conducted by Kurowski et al. [5] also points out the insufficient quality of CC by paramedics during simulated CPR.

Owing to advances in medical technology, systems supporting CC are becoming more and more popular, including devices that indicate the real-time depth and frequency of CC. Examples comprise the TrueCPR (Physio-Control; Redmond, USA) or automated chest compression systems, such as the Lifeline ARM chest compression system (ARM; Defibtech; Guilford, USA; Fig. 1), analysed in the study. The ARM system consists of three components: (1) a backboard, to be placed under the patient's back; (2) a frame embracing the patient's chest; (3) a compression piston that performs CC. The device is powered with

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Figure 1. The Lifeline ARM chest compression system

a built-in battery, whose full charge allows uninterrupted CC for 40 min. The unit can also be powered with a 230-V electricity supply. The first CPR mode handled by the ARM system is the standard regimen of 30 CC per two rescue breaths. After each 30 compressions, the device pauses, allowing rescue breaths to be performed. In the second mode, the so-called asynchronous CPR is implemented. When airway patency is secured (with endotracheal intubation as the “gold standard”) there is no need for any interruptions in CC in order to perform rescue breaths; therefore, the device consecutively continues to apply CC at the rate of 100/min. The ARM device can be used in patients with chest height greater than 16 cm, thus also in older children and adolescents.

The aim of the study was to evaluate the effectiveness of CC during the standard basic life support (Standard BLS) and those performed with the use of the Lifeline ARM system. The reference point for assessing the CPR effectiveness was the manikin software indications.

METHODS

The study was approved by the Program Council at the International Institute of Rescue Research and Education (No. of approval: 16.2015.12.05) and is designed as a randomised simulation crossover study. The study involved 37 nurses without prior experience regarding the use of chest compression systems. The study constitutes a continuation of former research concerning the effectiveness of chest compressions [4, 5].

Prior to the main study, all participants were informed about its purpose and voluntarily expressed their willingness

to participate. In addition, all persons taking part in the study joined a 20-min training on paediatric CPR and the use of chest compression systems during CPR. On introducing the theoretical background, the instructors demonstrated the correct CPR technique and the technique of the Lifeline ARM chest compression system application. After the presentation, all participants took part in a 10-min training session referring to Standard BLS and ARM system CPR.

In order to simulate a six-year-old paediatric patient with SCA, the authors employed a PediaSIM manikin (CAE Healthcare; Sarasota, FL, USA).

The study participants performed asynchronous CPR for 2 min, applying non-interrupted CC. The order of the participants to implement CPR, as well as the sequence of resuscitation methods, were randomly assigned on the basis of the Research Randomiser (www.randomizer.org), which was used to divide the participants into two groups. The first group performed Standard BLS CPR, and the other implemented CPR with the use of the chest compression system described above. After a 2 min cycle of CPR, the study participants were allowed a 20-min break, and then a change in the CPR method followed. The randomisation procedure is shown in detail in Figure 2.

During the study, the following parameters were evaluated: the total number of CC, the frequency of compressions (min^{-1}), compression depth (mm), as well as the percentage of correctly performed chest compressions and total chest decompressions. The parameters were monitored with the use of computer software compatible with the deployed manikin. The study participants had no insight into the manikin monitoring system, and performed the CPR as guided by their own experience. After each resuscitation attempt, the respondents were asked to identify their preferences with regard to CPR techniques. The rating was based on a 1–10 scale (1 — useless technique, 10 — definitely useful technique).

Statistical analysis

All statistical analyses were performed with the use of the Statistica 12 PL for Windows software (StatSoft, Inc.; Tulsa, OK, USA). Data were presented as median and interquartile range (IQR), mean and standard deviation (\pm SD), or number and percentage (%). The occurrence of normal distribution was confirmed by the Kolmogorov-Smirnov test. T-test for paired observations was applied for data with normal distribution, and the Wilcoxon test for paired observations in the case of data with non-normal distribution. Stuarta-Maxwell’s test was used to compare the frequency of CC. The Wilcoxon test for paired observations served to compare paired observations. In the comparative analysis of CC depth, as well as the personal variables (weight, height, body mass index [BMI], sex), simple linear regression analysis (Pearson) was applied to detect and describe the strength and direction of correlations of CC depth to above body composition data. The results were considered statistically significant at the value of $p < 0.05$.

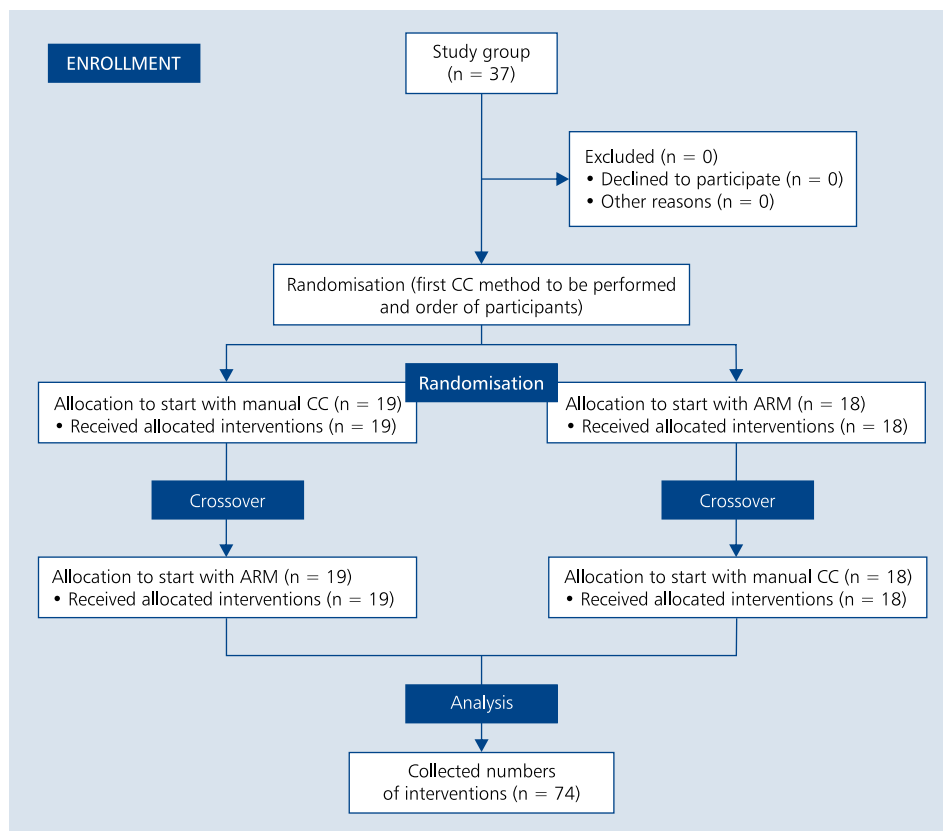


Figure 2. Study randomisation flow chart; CC — chest compressions; ARM — Lifeline ARM device

Table 1. The test parameters. The results are presented as percentage or median (interquartile range)

Parameter	Chest compression method		P
	Standard BLS	ARM	
Total number of chest compressions	313 (300–366)	200 (195–205)	< 0.001
Frequency of compressions [min^{-1}]	159 (135–163)	100 (98–102)	< 0.001
Compression depth [mm]	33 (27–37)	42 (40–44)	0.004
Correctly performed chest compressions	37.3%	100%	< 0.001
Total chest decompressions	64.6%	100%	< 0.001

ARM — Lifeline ARM chest compression system (Defibtech); BLS — basic life support (manual chest compressions)

RESULTS

In total, 37 registered nurses (including 25 women; 67.6%) participated in the study. The average age of the participants was 32.5 ± 5.4 years, the average work experience 8.5 ± 4.2 years, the mean height 167 ± 6 cm, and the mean body weight 67 ± 14 kg.

The results of the tests are shown in Table 1. The median frequency of CC in the analysed groups was differentiated and equalled 159 (IQR [135–163]) min^{-1} for Standard BLS chest compressions, and 100 [98–102] min^{-1} for the ARM system chest compressions. The analysis showed statistically significant differences in the frequency of CC between the

Standard BLS and ARM methods ($p < 0.001$). The average depth of a CC was 33 (27–37) mm in the Standard BLS group and 42 (40–44) mm in the ARM group ($p = 0.004$). Moreover, the analysis proved the differences in the percentage of correctly performed CC between the Standard BLS and ARM groups to be statistically significant ($p < 0.001$). In the case of the ARM technique, complete chest decompression was achieved after each compression (100%), whereas in the Standard BLS group it was observed only in 64.6% of cases ($p < 0.001$) (Table 1).

Simple regression analyses showed that male gender was significantly associated with a CC depth ($r = 0.32$, $p = 0.017$).

Table 2. Results of simple regression analyses between chest compressions depth and body composition data

Personal variables	R	p
Sex male	0.32	0.017
Weight	0.18	0.104
Height	0.11	0.092
Body mass index	0.15	0.127

Other variables (weight, height, BMI) were not significantly associated with CC depth. Detailed results of the regression analysis are presented in Table 2.

After completing the test, the respondents assessed their preferences with regard to applying both CPR techniques (Standard BLS and ARM) in clinical practice. Resuscitation with the use of the ARM system gained the average score of 8 (7–9) points, and was far more preferable than the Standard BLS method, which received 4.3 (3.5–5) points on average. The difference was statistically significant ($p < 0.001$).

DISCUSSION

The study attempted to assess the effectiveness of CC performed with the use of two methods: Standard BLS chest compressions and those applied with the ARM system. This was the first world study to compare the above resuscitation techniques in simulated cardiac arrest in a paediatric patient.

Medical personnel, including medical doctors, nurses, and paramedics, should possess the ability to effectively perform CC. Effective CC constitute an essential CPR element, increasing the chances of survival in an SCA patient [1, 6–11]. As proven in the subject literature, to carry out effective CPR is a challenge for medical personnel [11, 12]. Proper hand position during CC, appropriate frequency of CC, and adequate compression depth are only some of the parameters that should be paid attention to when performing CC [13].

The ERC resuscitation guidelines recommend that CC in children are performed with the frequency of at least 100 compressions/min and not more than 120/min [1]. In the present study, the chest compression rate when the ARM system was used equalled 100/min. In the case of manual CC, the rate of compressions was much higher than recommended, with the average of 159 compressions/min. As has been proven in literature, although a higher frequency of CC (more than 120/min) is associated with improved coronary blood flow, this does not affect the survival of SCA patients. Moreover, performing CPR with higher CC frequency significantly influences the rescuer's fatigue and thus subsequently worsens the quality of CC [14, 15].

Another parameter that should be paid attention to during CC is the compression depth. The 2015 ERC guidelines recommend to perform CC to the depth of 5–6 cm in adults, and to 1/3 of the sagittal thorax height in children [1, 2]. Numerous studies indicate that performing manual

CC without the use of supportive systems does not provide the optimum compressions depth. Compressions during Standard BLS resuscitation are uneven. In the present study, the implementation of the ARM system significantly improved the depth of CC as compared with the Standard BLS method, the difference being statistically significant. A proper compression depth enables correct CC and thus allows better perfusion to vital organs, including the heart, central nervous system, or lungs.

Our study shows only the correlation between male sex and depth of CC. Men performed CC deeper than women. It did not concern weight, height and BMI depth of CC. Research during resuscitation of adults has shown that people with higher BMI perform deeper compressions of the chest [16, 17]. The difference in these results may be due to the fact that in the case of children CPR requires less depth of CC compared with adults CPR.

Appropriate CC in children should be performed with the frequency of 100–120/min, and the depth of 1/3 of the sagittal thorax height; equal time of CC and decompression should be maintained. A total decompression of the chest allows chest extension and myocardial relaxation, and increases blood inflow to the heart [18]. Failure to achieve proper chest decompression results in a decrease of resuscitation effectiveness. In the present study, 100% chest decompression was achieved only in the ARM group. With manual CC, the nurses performed proper chest decompression only in 64.6% of cases; in the remaining 35.4% the relaxation phase was not sufficient.

Limitations of the study

The presented study has several limitations. The first one is the fact that it was carried out in a simulated setting. However, in accordance with the recommendations of the International Liaison Committee on Resuscitation, randomised trials concerning CPR are unethical; furthermore, manikin studies allow repeatability of rescue activities without any detriment to a potential patient's health. The second limitation of the study is the small group of participating professional nurses. Thirdly, the described CC system can be used in children with a minimum chest height of 16 cm, which excludes the application of this resuscitation technique in the youngest children.

CONCLUSIONS

The implementation of the Lifeline ARM chest compression system significantly improves the effectiveness of CC in the simulated paediatric resuscitation setting. Further studies are needed, including those among other medical professional groups, to confirm the results.

Ethical considerations: *The content presented in the article is consistent with the Declaration of Helsinki, European Union directives, and harmonised standards for biomedical journals.*

Conflict of interest: none declared

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Czy zastosowanie systemu kompresji klatki piersiowej u dzieci poprawia efektywność jej uciskania? Symulacyjne randomizowane krzyżowe badanie pilotażowe

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Streszczenie

Wstęp: Zapewnienie wysokiej jakości uciskania klatki piersiowej stanowi kluczowy element wpływający na skuteczność resuscytacji krążeniowo-oddechowej.

Cel: Celem pracy była ocena efektywności uciskania klatki piersiowej metodą standardową (bezpłynową) (Standard BLS, *standard basic life support*) oraz z wykorzystaniem systemu kompresji klatki piersiowej Lifeline ARM (ARM; Defibtech).

Metody: Badanie zaprojektowano jako randomizowane badanie krzyżowe. Wzięło w nim udział 37 pielęgniarek. Wykonywały one w sposób randomizowany 2-minutową asynchroniczną resuscytację z wykorzystaniem metody Standard BLS lub systemu ARM. Mierzono następujące parametry: całkowitą liczbę uciśnień klatki piersiowej, częstotliwość uciśnień (min^{-1}), głębokość ucisku (mm) oraz odsetek poprawnie wykonanych uciśnień klatki piersiowej i całkowitych dekompresji klatki piersiowej. Analizowano także preferencje uczestników badania dotyczące zastosowania danej techniki resuscytacji krążeniowo-oddechowej podczas pracy klinicznej.

Wyniki: Wyniki uzyskane w badaniu symulacyjnym podczas resuscytacji z wykorzystaniem systemu ARM były statystycznie istotnie lepsze niż w przypadku metody Standard BLS ($p < 0,05$) w przypadku wszystkich analizowanych parametrów.

Wnioski: Podczas badania w warunkach symulowanej resuscytacji dziecka wykonywanej przez pielęgniarki zastosowanie systemu kompresji klatki piersiowej Lifeline ARM w znaczący sposób poprawiało efektywność uciskania klatki piersiowej.

Słowa kluczowe: resuscytacja, efektywność, symulacja, dziecko

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