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Original Contribution

Randomized trial of the chest compressions effectiveness comparing 3 feedback CPR devices and standard basic life support by nurses☆,☆☆,★

Zenon Truszewski, PhD, MD [a], Lukasz Szarpak, PhD, DPH, EMT-P [a,*], Andrzej Kurowski, PhD, MD [b], Togay Evrin, PhD, MD [c], Piotr Zasko, MD [b], Lukasz Bogdanski, MD [b], Lukasz Czyzewski, PhD, RN [d]

[a] *Department of Emergency Medicine, Medical University of Warsaw, Warsaw, Poland*
[b] *Department of Anesthesiology, Cardinal Wyszynski National Institute of Cardiology, Warsaw, Poland*
[c] *Department of Emergency Medicine, UFuK University Medical Faculty, Dr Ridvan Ege Education and Research Hospital, Ankara, Turkey*
[d] *Department of Nephrologic Nursing, Medical University of Warsaw, Warsaw, Poland*

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ABSTRACT

Background: Out-of-hospital cardiac arrest is a leading cause of mortality and serious neurological morbidity in Europe. We aim to investigate the effect of 3 cardiopulmonary resuscitation (CPR) feedback devices on effectiveness of chest compression during CPR.
Methods: This was prospective, randomized, crossover, controlled trial. Following a brief didactic session, 140 volunteer nurses inexperienced with feedback CPR devices attempted chest compression on a manikin using 3 CPR feedback devices (TrueCPR, CPR-Ezy, and iCPR) and standard basic life support (BLS) without feedback.
Results: Comparison of standard BLS, TrueCPR, CPR-Ezy, and iCPR showed differences in the effectiveness of chest compression (compressions with correct pressure point, correct depth, and sufficient decompression), which are, respectively, 37.5%, 85.6%, 39.5%, and 33.4%; compression depth (44.6 vs 54.5 vs 45.6 vs 39.6 mm); and compression rate (129.4 vs 110.2 vs 101.5 vs 103.5 min^{-1}).
Conclusions: During the simulated resuscitation scenario, only TrueCPR significantly affected the increased effectiveness compression compared with standard BLS, CPR-Ezy, and iCPR. Further studies are required to confirm the results in clinical practice.

1. Introduction

Sudden cardiac arrest (SCA) is a major cause of death worldwide [1,2]. Survival of out-of-hospital cardiac arrest ranges from 4.3% to 10.7% [3,4]. The key procedure in the SCA is to perform as soon as possible cardiopulmonary resuscitation (CPR). Properly performed external chest compression (CC) has a direct impact on increasing the chance of survival in SCA as well as reduces the potential neurological complications resulting from hypoxia [5–9].

The current guidelines of the European Resuscitation Council (ERC 2010) recommend conducting external CC in an adult with a frequency of 100-120 min^{-1}. Chest compressions should be performed on the 1/3 of thoracic sagittal height (5-6 cm), and the time of CCs should be the same as the relaxation time [10].

Many publications have indicated that CCs are largely carried out incorrectly. Compression depth is too small, and CC does not end its full relaxation [7,11–13]. Useful in improving the efficiency may be feedback devices that provide information about the quality of the CC, such as, for example, compression depth and rate of CC [14–17].

The study aims to compare the impact of different prompt and feedback devices on quality of CC.

2. Materials and methods

2.1. Study design

This study was conducted between May and August of 2014. One hundred sixty nurses received training in CC with the feedback devices, organized by the International Institute of Rescue Research and Education (Warsaw, Poland). All participants had previous experience in CPR; however, none of them had used feedback devices before. This study was approved by the Executive Scientific Committee of the International Institute of Rescue Research and Education (Prot. Number: 4.2014.11.23).

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* Corresponding author at: Department of Emergency Medicine, Medical University of Warsaw, Lindleya Str. 4; 02-005 Warsaw, Poland. Tel.: +48 500186225.
E-mail address: lukasz.szarpak@gmail.com (L. Szarpak).

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First, we conducted 30-minute training for all participants including an introduction to pathophysiology cardiac arrest and the techniques of CC using TrueCPR (Physio-Control, Inc, Redmond, WA), CPR-Ezy (Health Affairs Ltd, Hertfordshire, UK), iCPR application for iPhone and iPod (www.iCPR.it) and standard (without instrumented) CPR (standard basic life support [BLS]). At the end of training session, the participants practiced the use of those CC devices.

All CPR sessions were done with the CPR training manikin METIman Prehospital (CAE HealthCare, Saint-Laurent, Quebec, Canada). Each participant performed CPR using all 4 CC methods in a computer-generated randomized sequence (Research Randomizer [18]). Participants performed 8 minutes of single-rescuer CPR with mouth-to-mouth ventilation according to ERC 2010 [10]. After each method, the participant took a 20-minute rest and then had to perform CPR using the next device. The participants were not allowed to watch each other to exclude a learning effect from observing. The compression depth, compression rate, incorrect decompressions, and incorrect hand position were measured. Participants also evaluated the "ease of use," "comfort of use," "level of confidence," and "level of distraction" for each device. Answers were rated on a 5-point Lickert scale (1 = worst, 5 = best).

Apart from those data, sociodemographic data such as sex (female, male), age (in years), body mass index (BMI), level of education (bachelor, master), work experience (in years), and work place (emergency medical service, emergency department [ED]) were documented.

2.2. Statistical analysis

Data were analyzed using the R statistical package for Windows (version 3.0.0). Results were presented as mean ± SD and frequencies and percentages. The differences in effectiveness of individual parameters of CC were analyzed using the χ^2 test of independence. Moreover, multivariate regression analysis was used to assess the impact of sex, age, work experience, work place, and level of education on effectiveness of CC. P values < .05 were considered as statistically significant.

3. Results

3.1. Study population

One hundred forty nurses (102 female, 73.6%) participated in this study. The average BMI of study participants was 23 ± 1.5. No participant had previously performed CC with feedback devices. Ninety-seven (78 female, 79.6%) worked in hospital emergency units, and 43 participants (24 female, 55.8%) worked in emergency medical service teams. Mean age was 35.6 ± 11.4 years, and mean work experience was 12.4 ± 6.8 years.

3.2. Compression depth

The mean compression depths using standard BLS, TrueCPR, CPR-Ezy, and iCPR are presented in Table 1. The analysis showed that the correct compression depth (50-60 mm) was archived when using TrueCPR (54.5 ± 9.5 mm) and the shallowest when using iCPR (39.6 ± 12.5 mm). A statistically significant difference was noticed between standard BLS and TrueCPR (P < .001) and iCPR (P = .031), between TrueCPR and CPR-Ezy (P < .001) and iCPR (P < .001), and also between CPR-Ezy and iCPR (P = .023).

The analysis showed that the largest percentage of too-shallow compressions was archived when using iCPR (36.6% ± 13.1%) and the smallest when using TrueCPR (10.9% ± 74.7%). A statistically significant difference was noticed between TrueCPR and standard BLS (P < .001) and iCPR (P < .001).

Table 1
Baseline characteristics

CC parameter	CC method				P value
	Standard BLS	TrueCPR	CPR-Ezy	iCPR	
Effective compression[a] (%)	37.5 ± 16.5	85.6 ± 7.4	39.5 ± 12.9	33.4 ± 23.7	TrueCPR vs standard BLS <.001 TrueCPR vs CPR-Ezy <.001 TrueCPR vs iCPR <.001 Others: NS
Compression depth (mm)	44.6 ± 15.8	54.5 ± 9.5	45.6 ± 9.5	39.6 ± 12.5	Standard BLS vs TrueCPR <.001 Standard BLS vs iCPR = .031 TrueCPR vs CPR-Ezy <.001 TrueCPR vs iCPR <.001 CPR-Ezyvs iCPR = .023 Others: NS
Compression too shallow (<50 mm) (%)	33.5 ± 11.4	10.9 ± 7.7	25.5 ± 14.9	36.6 ± 13.1	TrueCPR vs standard BLS <.001 TrueCPR vs iCPR <.001 Others: NS
Compression too deep (>60 mm) (%)	5.6 ± 8.5	12.5 ± 4.6	14.1 ± 13.4	14.7 ± 12.4	Standard BLS vs CPR-Ezy = .034 Standard BLS vs iCPR = .032 Others: NS
Compression rate (min^{-1})	129.4 ± 22.4	110.2 ± 5.8	101,5 ± 4.8	103.5 ± 22.6	Standard BLS vs TrueCPR <.001 Standard BLS vs CPR-Ezy <.001 Standard BLS vs iCPR <.001 TrueCPR vs CPR-Ezy <.001 TrueCPR vs iCPR <.001 Others: NS
Incorrect decompressions (%)	31.6 ± 5.4	21.5 ± 9.7	30.4 ± 17.5	34.5 ± 12.2	TrueCPR vs standard BLS = .018 TrueCPR vs CPR-Ezy = .021 TrueCPR vs iCPR = .001 Others: NS
Incorrect pressure point (%)	5.4 ± 3.2	1.8 ± 1.1	6.7 ± 4.8	23.4 ± 15.4	TrueCPR vs standard BLS = .019 TrueCPR vs CPR-Ezy = .013 TrueCPR vs iCPR <.001 iCPR vs standard BLS <.001 iCPR vs CPR-Ezy <.001 Others: NS

NS = not statistically significant.
[a] *Effective compression* was defined as compression with correct depth (50-60 mm), compete decompression, and correct hand position.

Also in the case of too-deep compressions, the most frequent was archived when using iCPR (14.7% ± 12.4%). In this case, statistically significant difference was noticed between standard BLS and CPR-Ezy ($P = .034$) and iCPR ($P = .032$).

3.3. Compression rate

The mean compression rate using standard BLS, TrueCPR, CPR-Ezy, and iCPR varied and amounted to 129.4 min^{-1} vs 110.2 min^{-1} vs 101.5 min^{-1} vs 103.5 min^{-1}. There was a statistically significant difference in the compression rate between standard BLS and TrueCPR ($P < .001$), CPR-Ezy ($P < .001$), and iCPR ($P < .001$), and between TrueCPR and CPR-Ezy ($P < .001$) and iCPR ($P < .001$).

3.4. Proportion of compressions with incomplete release

The use of TrueCPR device was the only device which reduced increased the proportion of CC with inadequate depth, and the inadequate incorrect decompression was statistically significantly lower when using TrueCPR (21.5%) compared with standard BLS (31.6%; $P = .018$), CPR-Ezy (30.4%; $P = .021$), and iCPR (34.5%; $P = .001$).

3.5. Incorrect pressure point

The analysis showed the largest percentage of incorrect hand positioning when iCPR (23.4% ± 15.4%) was used and the smallest when TrueCPR (1.8% ± 1.1%) was used. There was statistically significant difference in the percentage of the incorrect pressure point between TrueCPR and standard BLS ($P = .019$), CPR-Ezy ($P = .013$), and iCPR ($P < .001$), and between iCPR and standard BLS ($P < .001$) as well as CPR-Ezy ($P < .001$).

3.6. Effective CC over time

The use TrueCPR device during resuscitation showed the highest level of proper CC among available methods. This proportion was highest both at the beginning of resuscitation (89.5%) as well as after 8 minutes of conducting BLS (76.3%), as illustrated in the Figure.

3.7. User satisfaction

Participants evaluated each device used during CC based on the subjective out of procedure. The feedback device which proved to be the highest rated device was the TrueCPR, which in terms of "ease of use" received an average rating of 3.9 points (Table 2). The TrueCPR device also received the highest ratings in other evaluated parameters.

3.8. Multivariate regression analysis

An analysis of variance test was used for multivariate analysis. The following sociodemographic variables were selected as independent variables: age (in age groups), sex (male and female), BMI (at intervals), education (bachelor, master), work experience (at intervals), and place of work (ED and emergency medical mobile team). The dependent variable is the efficiency of CC with regard to the distinct feedback devices analyzed (Table 3). We found a statistically significant impact of "age" on effectiveness of CC with standard BLS ($P = .032$): older participants displayed greater effectiveness during CC with standard BLS. We found a statistically significant impact of "BMI" on the efficacy of CC with standard BLS ($P = .028$) and iCPR ($P = .037$): participants with higher BMI displayed greater effectiveness of CC with standard BLS and iCPR.

Work experience significantly influenced the CC effectiveness of the standard BLS ($P = .043$) and iCPR ($P = .044$). People with more experience displayed greater CC effectiveness with standard BLS and iCPR. Work place also significantly influenced the CC quality when using standard BLS ($P = .028$) and iCPR ($P = .032$). Participants working in the emergency medical service statistically significantly more than people working in ED performed effective CC in the case of standard BLS and iCPR.

4. Discussion

Improving the effectiveness of CPR increases survival in cardiac arrest, dating back to the last decade of the 20th century [19]. Conducting chest compressions, minimizing interruptions in CCs for rescue breathing or shock is affected by the outcome of resuscitation of the patient. The ERC guidelines recommend conducting CPR in adult patient with a frequency higher than 100 min^{-1} (but not more than 120 min^{-1}). As shown by Deschilder et al [20], resuscitation conducted in accordance with the recommended ratio of CCs to rescue breaths (30:2) is more exhausting than a rescuer CPR in the ratio of 15:2. Prolonged resuscitation may lead to rescuer fatigue, and thus they decrease the effectiveness of CPR. To improve efficiency, especially in the case of a prolonged resuscitation, using feedback devices can be used [14,15,21–23].

The first device to support resuscitation was introduced in 1992. Then, Kern et al [24] demonstrated conducting external CC using a

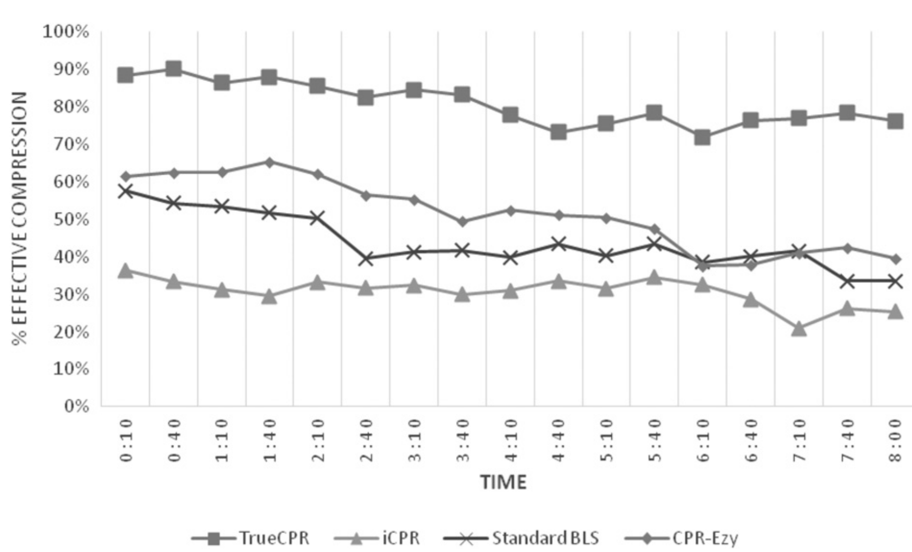

Figure. Effective CC over time.

Table 2
Median and SD user satisfaction score (1 = extremely difficult to 5 = extremely easy)

Scores	TrueCPR	CPR-Ezy	iCPR
Ease of use	3.9 ± 0.7	3.5 ± 2.1	2.5 ± 1.6
Comfort of use	4.3 ± 1.1	1.9 ± 1.3	1.4 ± 0.5
Level of confidence	4.5 ± 1.4	2.7 ± 1.9	1.3 ± 0.9
Level of distraction	1.3 ± 0.6	3.2 ± 1.2	3.6 ± 1.8

metronome. Since then, there has been considerable progress of medical technology; thus, many assistive resuscitation devices have appeared in the medical market. These include both mechanical (ie, Lucas 2, AutoPulse) as well as equipment requiring the rescuer to conduct manual CC but giving information feedback on the rate and depth of compressions.

In this study, we attempted to evaluate the effectiveness of 3 feedback devices—TrueCPR, CPR-Ezy, and telephone application iCPR—compared with standard CPR.

Effective compression was defined as compression with correct depth (50-60 mm); compete decompression and correct hand position are good indicators allowing to compare the efficacy of the tested devices. Our study confirmed other authors' reports that the use of feedback devices affects the effectiveness of CC compared with standard CPR [10]. The results of the analysis indicate that the effectiveness of resuscitation with standard BLS is only 37.5%. Low efficiency of the CC is also confirmed by Buléon et al (26%) [16] and Zapletal et al (35%) [25]. Maintaining proper coronary and brain perfusion is crucial for patient survival and reduction of neurological deficits [26]. In our study, only the use of TrueCPR significantly increased the efficiency of external CC. The explanation for this may be that TrueCPR has an accurate system monitoring both depth and rate of compressions, so the person conducting CC is able to immediately correct the quality of CCs. In contrast to the results of Semeraro et al [27], the use of CPR with the phone application iCPR reduced effective compression. These results show that even though feedback devices provide us with feedback on the rate and depth of the CC, and the effect of increasing the effectiveness of CC, some of them do not lead to improvement of the efficiency.

Our results showed that the use of iCPR results in a reduction of the depth of compression over standard CPR or the use of TrueCPR and CPR-Ezy.

Surprisingly, it turned out that the frequency of the CC of the standard BLS went beyond the norm (ERC 2010) (100-120 min^{-1}) and amounted to 129 min^{-1}. In the case of feedback devices, the frequency was within the normal range. Studies by other authors also suggest that the use of feedback devices results in both correct rate of compressions [16,21] and improving the depth of compression [14,15,21].

The correct ratio of CCs to its decompression is crucial to the use of CCs as a "pump" to produce organ perfusion. Studies by Niles et al [28] that the use of the accelerometer reduces the percentage of incomplete release during pediatric resuscitation. Results obtained in the present study are confirmation of the abovementioned study and indicate that, in the case TrueCPR and CPR-Ezy, the percentage of incorrect decompressions compared with standard BLS was lower. Only the use of iCPR resulted in the return of incorrect decompressions.

Improper hand position during CPR is a serious problem that could lead to ineffective resuscitation as well as numerous injuries on both the rescuer and the patient. In our study, percentage of CCs with incorrect position of hands was the lowest in the case of TrueCPR (1.8%), followed by the standard (no device used) BLS (8.2%) and CPR-Ezy (6.7%), whereas the largest percentage concerned CC with the use of phone with iCPR application (23.4%). Zapetal et al [25] also showed statistically significant differences in the improper position of hands in a standard BLS and TrueCPR compared with using proper phone application.

As indicated by study participants alone, the best assessment of both the ease and comfort of use is reported for the TrueCPR device. The highest level of trust was also placed in the TrueCPR device by the respondents. The iCPR phone application turned out to be the worst, which is also confirmed in the abovementioned data on the effectiveness of CPR compressions and the depth or the frequency of compressions.

Multivariate analysis performed on the starting material showed that only in the case of TrueCPR was the efficiency of indirect cardiac massage not affected by age, sex, education, work experience, or work place. This demonstrates the possibility of using this device for each rescuer regardless of experience in the field of resuscitation.

Conducted multivariate analysis indicated the effect of BMI on the CC quality. People with higher BMI conducted greater-efficiency CCs. However, this correlation was observed for standard BLS and use of iCPR. In the case of TrueCPR and CPR-Eazy, there was no effect of BMI on the quality of CCs. Chi et al [29] in their study indicated the importance of BMI when conducting CC. In their study of 95 participants, only 36 (37.9%) performed high-quality CPR on a manikin. Chi et al [29] also pointed out the importance of experience on the effectiveness of CPR. In the present study, work experience also had an influence only in case of conducting CC with standard BLS and with the use of iCPR. This can attest to the fact that the use of TrueCPR and CPR-Eazy improves the quality of CCs, thus eliminating the differences due to sex, age of rescuer, rescuer BMI, level of education, work experience, or work place.

This study has several limitations. The first is the fact that it has been carried out with a simulated training manikin. However, studies conducted on manikins allow repetition of rescue activities without damage to the health of the victim and at the same time allow you to recreate equal conditions of rescue operation for all the people involved in the study. The second limitation of this study is the narrow professional group participating in this study. To confirm the results obtained in the study, further study should be carried out among other medical professions.

There was a limitation in this study. This study was conducted in a manikin, and the use of a manikin may not fully reproduce CC conditions in humans. The use of a manikin was required to ensure similarity of CC scenario. Therefore, our study may be interpreted as evidence that the TrueCPR is the most efficacious feedback device for CC in humans.

Table 3
Multivariate regression analysis—the impact on the results

CC method	Statistical parameter	Sociodemographic parameter					
		Sex	Age	BMI	Level of education	Work experience	Work place
Standard BLS	β	0.032954	0.037582	0.039628	0.038532	0.038927	0.048925
	P value	.056	.032	.028	.063	.043	.028
TrueCPR	β	0.034478	0.037843	0.036582	0.048937	0.047823	0.034284
	P value	.593	.762	.682	.377	.237	.319
CPR-Ezy	β	0.048963	0.047832	0.361442	0.039845	0.038567	0.048237
	P value	.0285	.196	.591	.188	.087	.062
iCPR	β	0.048394	0.042984	0.039636	0.047832	0.039281	0.039852
	P value	.831	.241	.037	.119	.044	.032

We believe that our results are sufficiently encouraging to promote clinical studies seeking out further improvements in the current status of CPR.

5. Conclusions

Although CPR feedback devices are designed to facilitate the process of resuscitation, our research shows that not all of these devices should be used. During the simulated resuscitation scenario, only TrueCPR significantly increased the effectiveness of compression compared with standard BLS, CPR-Ezy, and iCPR. Further studies are required to confirm the results in clinical practice.

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