Submitted: 25 September, 2020 Accepted: 22 October, 2020 Published: 08 January, 2021 DOI:10.22514/sv.2020.16.0110

Open Access
Signa Vitae

ORIGINAL RESEARCH

Automatic compression improves adherence to advanced life support protocol in two-paramedic team. A randomized simulation study

Tomasz Kłosiewicz[1,*], Mateusz Puślecki[1,2], Łukasz Szarpak[3,4,5], Marek Dąbrowski[6], Bartłomiej Perek[2]

[1]Department of Medical Rescue, Poznan University of Medical Sciences, 7 Rokietnicka Street, 60608 Poznań, Poland
[2]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, 1/2 Długa Street, 61-848 Poznań, Poland
[3]Maria Sklodowska-Curie Bialystok Oncology Center,12 Ogrodowa Street, 15-027 Białystok, Poland
[4]Maria Sklodowska-Curie Medical Academy in Warsaw, Aleja Solidarności 12/4, 03-411 Warszawa, Poland
[5]Polish Society of Disaster Medicine, PO box 78, 05-090 Raszyn Warsaw, Poland
[6]Department of Medical Education, Poznan University of Medical Sciences, 7 Rokietnicka Street, 60-608 Poznań, Poland

***Correspondence**
klosiewicz.tomek@gmail.com
(Tomasz Kłosiewicz)

Abstract

Introduction: The use of protocols reduces the risk of human error and increases healthcare professionals' adherence to guidelines. In a team of only two providers, following Advanced Life Support (ALS) protocol might be challenging. Automated Chest Compressions Devices (ACCD) may increase the quality of chest compressions. The aim of this study was to evaluate if the use of ACCD in resuscitation by a two-paramedic crew improves adherence to the ALS protocol. **Materials and Methods**: This study was designed as a prospective randomized high-fidelity cross-over simulation trial. Fifty-two doubleperson teams were enrolled. Each team performed two full resuscitation scenarios: one with ACCD (the experimental group-ACC) and one with manual compressions (the control group-MAN). **Results**: ACC achieved shorter mean durations of resuscitation loops, being less prolonged in relation to recommended durations than MAN (13 vs. 23 sec over recommended respectively, $P = 0.0003$). ACC also achieved mean times for supraglottic airway completion significantly faster than MAN: 224 $\pm$ 66 s vs 122 $\pm$ 35 s ($P < 0.0001$). In ACC, the intravenous line was obtained earlier then in MAN (162 $\pm$ 35 s vs 183 $\pm$ 45 s, $P = 0.0111$). Moreover, the first and second doses of adrenaline (epinephrine) were administered earlier 272 $\pm$ 58 s vs 232 $\pm$ 57 s ($P = 0.0014$) for the first and 486 $\pm$ 96 s vs 424 $\pm$ 69 s ($P = 0.0007$) for the second doses, respectively. Mean chest compression fraction (CCF) in MAN group was significantly lower (74 $\pm$ 4%) than in ACC group (83 $\pm$ 2%) ($P < 0.0001$). **Conclusions**: In a simulated setting, ACCD used by two-person paramedic teams yielded earlier achievement of resuscitation endpoints and improved delivery time of compressions. which may have implications for effective clinical resuscitation.

Keywords

Quality of health care; Advanced cardiac life support; Cardiopulmonary resuscitation; Automated Chest Compression; High fidelity simulation training

1. Introduction

One-year survival rates for sudden cardiac arrest (SCA) victims remain poor, despite some improvements in trends over time from 1985 to 2018 [1]. Only immediate delivery of high-quality chest compressions (CC) and defibrillation in cases of ventricular fibrillation (VF) followed by appropriate implementation of post-resuscitation care have been linked to to improved survival and neurologic outcomes [2].

The Advanced Life Support (ALS) protocol, in addition to high-quality CC and ventilation, also includes critical elements such as heart rhythm analysis, defibrillation, intravascular access and drug administration. Although basic procedures are essential, recent studies have revealed benefits when basic life support (BLS) is followed by administration of ALS protocols within 11 minutes of CPR [3]. Adrenaline improved survival until hospital discharge and resulted in a meaningful clinical outcome according to a 2019 review and meta-analysis. [4]. However, cumulative doses of adrenaline may provoke vasoconstriction leading to stroke or myocardial ischaemia, prompting the recommendation for administration at proper intervals. Continuous assessment of the quality of resuscitation should be performed during the whole action. There is also a need to ensure proper diagnosis for potentially reversible causes of cardiac arrest. Performing these various tasks in a short period of time requires excellent organization and is the basis for the effectiveness of the resuscitation team. Furthermore, exposure of paramedics to actual resuscitation cases is low [5]. In a central European agglomeration, paramedics' response to SCA was estimated at 1% of all emergency ambulance responses [6]. Even the presence of experienced staff does not always guarantee high-quality care. These

aforementioned factors oblige practitioners to find methods that will optimize the quality of resuscitation [7].

Protocols and guidelines ensure high-level care and reduce the risk of human errors when various tasks must be done effectively and urgently. A guideline recommendation is defined as any statement that promotes or advocates a particular course of action in clinical care [8]. The protocol is a pathway of treatment developed based on guidelines. It indicates step by step what activities should be performed. It has been shown that the use of protocols increases healthcare professionals' adherence to guidelines [9]. Even when key personnel are present, adherence to the specific content and timing of guidelines is often unsatisfactory [10]. Ebben *et al*. indicate that in life-threatening situations, adherence to international emergency guidelines shows a wide variation [11]. McEvoy *et al*. found that the number of wrong actions undertaken during ALS correlated with survival rate [12]. Consequently, Cheskes *et al*. strongly recommended strategies to improve overall guideline compliance that might significantly impact outcomes after out-hospital cardiac arrest (OHCA) [13].

Automated Chest Compressions Devices (ACCD) seem to be a promising method that can improve quality of CC compared to manual compressions provided by rescuers, both in timing and compression depth. ACCD may also be useful for continued resuscitation during prolonged procedures, transport of patients, and advanced diagnostics or treatment procedures like computed tomography or percutaneous coronary intervention. Currently, there is no consensus on whether the use of these devices actually improves the outcome of SCA cases [14–16].

The aim of this study was to evaluate if the use of ACCD in resuscitation provided in two-paramedic teams helps in adherence to ALS protocols.

2. Materials and methods

2.1 Participants

A pilot study of 10 simulated resuscitation trials one month prior to the definitive study was performed to determine necessary sample size and feasibility. difference in duration of resuscitation loop during manual compressions in comparison to pattern was 10%. Assuming a type I error rate of 5% and power of 80%, a minimum of 30 teams were required. Eventually, we did decide to involve at least 50 pairs taking into account an attrition rate of even 20% (considered as marked).

Recruitment was conducted by the Department of Medical Rescue, Poznan University of Medical Sciences, Poznan, Poland in May and June of 2019, approximately one month before study simulations began. Participants were paramedics who had at least threeyears of experience in two-person ambulance teams. Only teams of paramedics working together for at least 75% of their professional time were qualified. Individuals not using ACCD in their daily practices were excluded. Each participant completed a certified ALS course. The training was voluntary and no external funding was acquired. The participants were acquainted with the simulator with the full spectrum of activities included in the study protocol. During prebriefing, teams were instructed how to use the available equipment and had the opportunity to practice with it. Printed educational materials of the ALS algorithm according to the 2015 European Resuscitation Council (ERC) guidelines were provided.

2.2 Study design and environment

This study was designed as a prospective randomized high-fidelity cross-over simulation trial. A simulation was used as the investigational method of the research. The study was conducted in the closed simulation room of the Medical Simulation Center in Poznan, Poland between July and September 2019. The only people present in the room during each trial were the two study participants and an investigator. The observer was blinded as for to which group the participants belonged.

Simulation of a 10-minute adult male cardiac arrest scenario was created. Pulseless electrical activity (PEA) was the initial rhythm which converted automatically to ventricular fibrillation in the fifth minute of the scenario. After 10 minutes, the simulation was complete, regardless of the participants' actions.

2.3 Interventions

Each team completed the same scenario twice, once providing manual resuscitation (control group - MAN), and once using the automated CC device (experimental group - ACC). The LUCAS 2 Chest Compression System (Physio-Control, Redmond, Washington, USA) was used. Between the scenarios, the teams had at least 20 minutes for complete physical recovery. The flowchart of this study according to Consolidated Standards of Reporting Trials (CONSORT) statement is presented on Fig. 1.

2.4 Randomization and blinding

Recruitment leader has created a list of teams in the order of their applications to the survey. Then, using a free online research randomization tool (https://www.randomizer.org/), the leader established the order of scenarios for each team. We assumed that each group should have the same number of participants. Block randomization protocol was used. Each team was informed about the allocation to the first scenario in a sealed envelope. The allocation ratio was 1 : 1. They were informed that some of the groups performed manual compressions first while the other as second. Participant were informed that the study aimed evaluate the quality of CCs, but did not know that the time of individual interventions was also being evaluated.

2.5 Measurement procedure

The ResusciAnne Advanced Skill Trainer® (Laerdal Medical AS, Stavanger, Norway) human simulator was used in the study. The simulator allows generating a pulse in the area of thecarotid arteries, respirations, and heart rhythms which include ventricular fibrillation and sinus rhythm. Airway management with supraglottic devices and upper limbs adapted to insert an intravenous catheter were prepared. To secure airway I-Gel® laryngeal mask was also applied (Intersurgical, Wokingham, United Kingdom). The ZOLL M-Series® defibrilla-

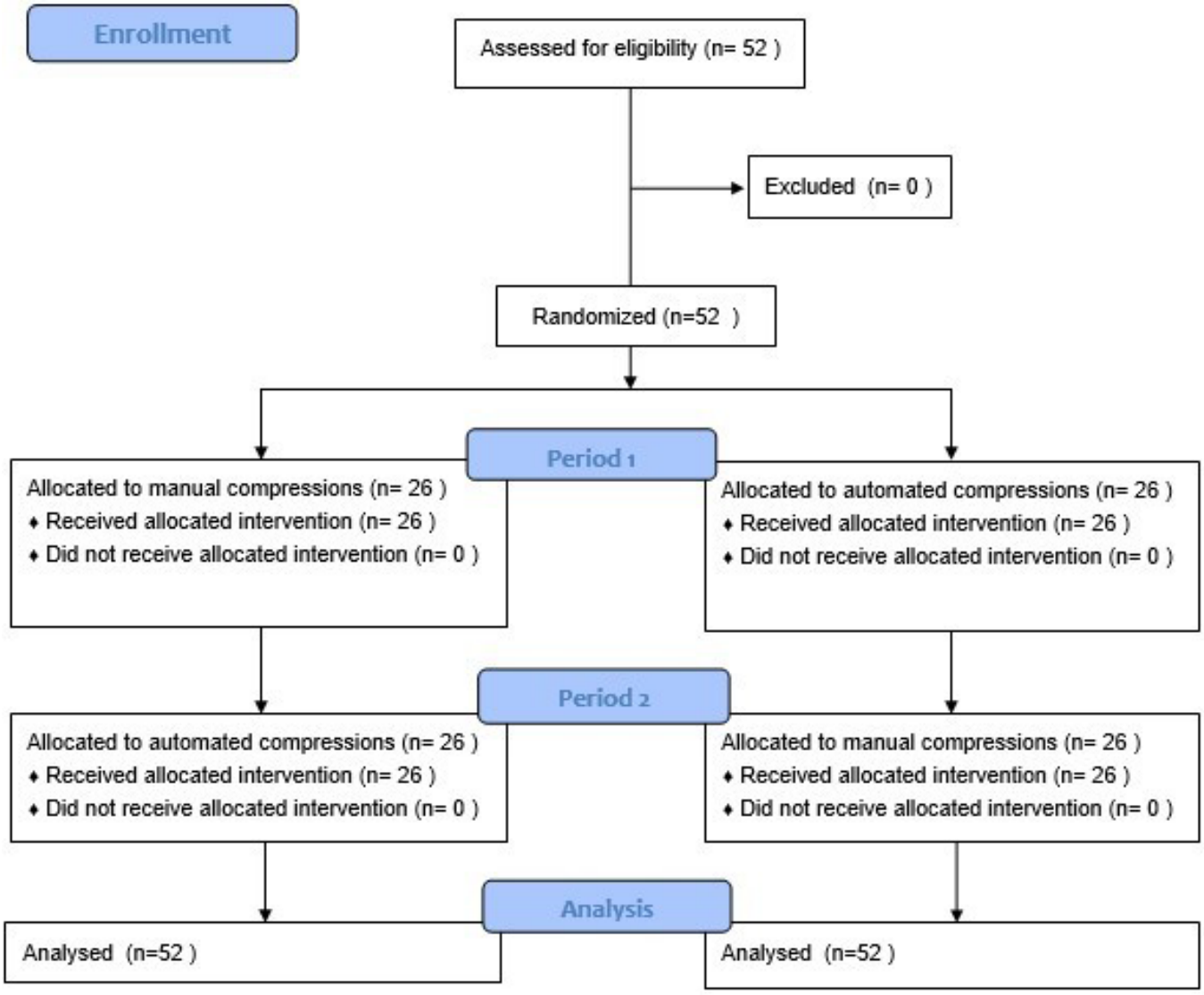

FIGURE 1. Study flowchart according to CONSORT statement.

tor (ZOLL Medical Corporation, Chelmsford, Massachusetts, USA) was used to monitor patients' hearth rhythms and provide electrotherapy. To minimize peri-shock compressions pause participants were asked to use the "charge & check" method of analysis. In this method proven to improve CC fraction (CCF) [14], the defibrillator is charged during the last ten seconds of the two-minute compressions loop.

During the study, the following parameters were monitored with Session Viewer Software 6.2.6400 (SimVentures, South Newlands, United Kingdom): time of each heart rhythm analysis (A1), analysis time for shockable (A2) and non-shockable (A3) rhythm, supraglottic airway device (SAD) insertion and preparation of ventilation times (A4), and time of performing compressions isolated from total scenario time, or CCF (A5).

2.6 Variables

Our primary outcomes were: duration of resuscitation loop; time and duration of heart rhythm analyses and its deviation from the pattern; time of administering the first dose of epinephrine and interval between its subsequent doses. The clock was stopped after 10 minutes even if a scenario with mandatory actions was not completed. All the findings were included in further statistical analysis.

For the purpose of the study, the timeline of model resuscitation was created according to ERC Guidelines 2015. This pattern is presented in Fig. 2. It was assumed that the first dose of adrenaline should be administered as soon as possible-subsequent doses optimally in 3-5 minutes intervals.

Our secondary outcomes were insertion times of intravenous line and SAD, as well as CCF.

To validate the simulation model and to check for any bias related to the scenarios sequence (MAN followed by ACCD vs. ACCD followed by MAN), at the beginning of our analysis, we compared the findings (both primary and secondary outcomes) in two subsets of MAN group, one in which manual chest compression scenario (MAN 1) was the first one versus the second one (MAN 2) (seen Table 1).

2.7 Statistical analysis

The quantitative variables were checked for normality distribution with the use of the Shapiro-Wilk W test. Variables satisfying normal distribution criteria were expressed as means

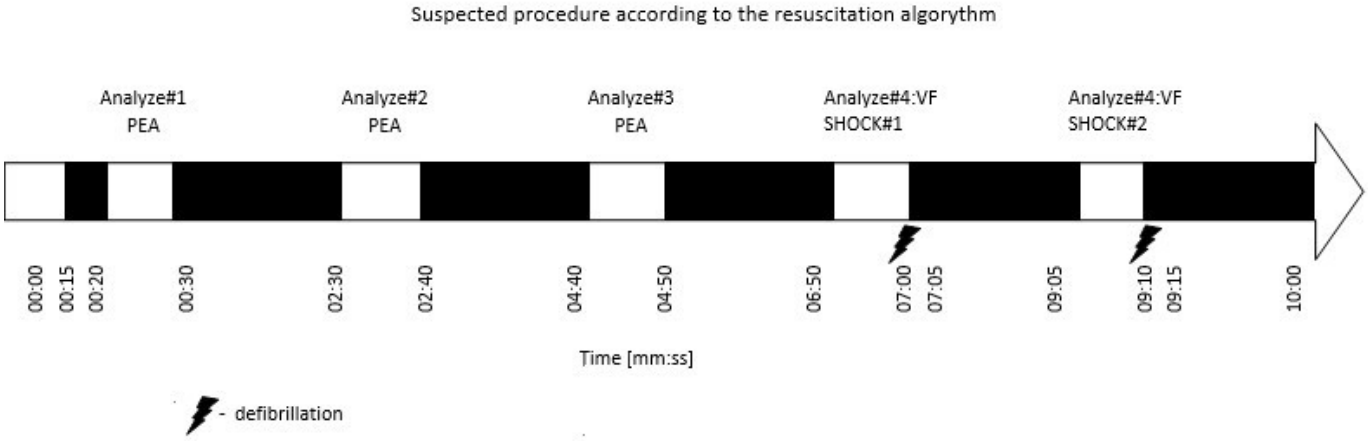

FIGURE 2. Timeline model for the research protocol.

TABLE 1. A Baseline demographics of participants randomized to study groups of (52 paramedics, 26 teams) each.

*	Manual compressions first	Automated compressions first
Age (years, mean ± standard deviation)	31.11 ± 4.65	30.73 ± 3.29
Profesional experience (years, mean ± standard deviation)	9.25 ± 4.22	9.00 ± 3.46
Sex (Males, females)	39, 13	31, 21

± standard deviation; non-normally distributed variables such as deviation between time periods recommended in ECR protocol and these obtained by participating paramedics were reported as medians and interquartile ranges (IQR) (25th - 75th percentiles). Categorical variables were presented as numbers (n) and percentages (%) and were analzyed using the Student t test (if normally distributed) or the Mann-Whitney Utest. *P* values less than 0.05 were considered significant. Statistical analyses were performed using Statistica 12 software (Tibco Inc., Tulsa, OK, USA).

3. Results

3.1 Participants

One hundred four paramedics (52 teams) were participated in thestudy. The sample consisted of 70 men and 34 women with the mean age of 30.9 ± 4.0 and average professional experience of 9.1 ± 3.8 years. Baseline demographics of participants in groups according to order of simulations is presented in Table 1.

3.2 Results of study protocol validation

There were no significant differences between MAN 1 and MAN 2 subset of patients, therefore we decided to continue further analysis of our simulation-based study (Table 2).

3.3 Primary outcomes

All events were completed within 600 seconds. The duration of the initial assessment of vital signs was comparable in both groups. In the group where ACCD was used, all times of analyzed parameters included in the study primary outcomes were markedly shorter (Table 3). Additional comparisons of the difference (Δ) between the time specified in the ERC protocol and the one reached by paramedics showed higher deviation from optimal (target) value in MAN group (Table 4).

The detailed dispersion for both groups is presented in Fig. 3 and Fig. 4.

Intervals between consecutive rhythm analyses in both studygroups were calculated. Interestingly, there were no differences in the intervals between first and fifth analysis (A5 - A1), probably because only 77% (the fastest 40 out of all 52) in the MAN group were able to carry out the fifth analysis. Therefore, we have also included analysis of A4-A1 interval as seen in Table 5.

During either manual or automated compressions, the time that paramedics spent for a reevaluation of the manikin was within the normal range. The differences between groups were only one second, but this result was found to be significant when PEA was presented on the monitor. In both groups, the rhythm analyses were longer for PEA than for VF (7 ± 1 s and 5 ± 1 s in MAN, 8 ± 2 s and 4 ± 1 s in ACC, respectively). The comparison of the described above findings is presented in Table 3.

The mean duration of a single resuscitation loop for MAN vs. ACC was 143 ± 17 s vs 133 ± 11 s (*P* value if available?). The difference between MAN and the recommended ERC protocol time was 23 s, significantly longer than that of ACC's difference of 13 s (*P* = 0.0003).

The first and second doses of adrenaline (epinephrine) were administered earlier in ACC vs. MAN (272 ± 58 vs 232 ± 57 for the first dose and 486 ± 96 vs 424 ± 69 for the second dose). Adrenaline was administered three times in one MAN simulation but four ACC scenarios. Therefore the time of the third dose was excluded from further comparisons. All of these results were significantly different as presented in Table 6.

TABLE 2. A comparison of the findings in manual chest compression group (MAN) with respect to its sequence (the first (MAN 1) or second (MAN 2)) in the study scenario.

*	MAN 1 [n = 26 teams]	MAN 2 [n = 26 teams]	*P*-value
Loop time [s]	143 ± 18	144 ± 17	0.8023
$1^{st\&}$ analysis [s]	30 ± 5	27 ± 7	0.0879
2^{nd} analysis [s]	173 ± 23	183 ± 47	0.2375
3^{rd} analysis [s]	305 ± 49	315 ± 51	0.0974
4^{th} analysis [s]	442 ± 41	456 ± 60	0.0854
5^{th} analysis [s]	546 ± 31	558 ± 42	0.3467
1^{st} dose of epinephrine [s]	265 ± 56	278 ± 62	0.4499
2^{nd} dose of epinephrine [s]	478 ± 96	491 ± 72	0.3555
Intervals between epinephrine [s]	225 ± 46	223 ± 62	0.4559
IV line placed [s]	183 ± 52	182 ± 38	0.9171
SAD insertion time [s]	215 ± 41	225 ± 82	0.5658
CCF [%]	74.6 ± 2.4	73.8 ± 4.4	0.3923

**All variables are presented as the means ± standard deviation. &analysis - number of following heart rhythm analyzes. #time between consecutive doses of epinephrine Abbreviations: CCF - chest compression fraction, MAN - manual chest compression group, SAD - supraglottic airway device. There were no performance differences between the teams randomized to use MAN first vs. second.*

TABLE 3. A comparison and the statistical summary of rhythm analyzes and loops time.

*	Control (MANUAL) [s]	Experimental (ACCD) [s]	*P*-value
ABC	16 ± 2	15 ± 2	0.0683
1^{st}# analysis	29 ± 6	24 ± 7	0.0002
2^{nd} analysis	177 ± 38	158 ± 18	0.0024
3^{rd} analysis	311 ± 50	291 ± 21	0.0107
4^{th} analysis	449 ± 54	416 ± 28	0.0002
5^{th} analysis	551 ± 36	538 ± 25	0.0362
Loop time	143 ± 17	133 ± 11	< 0.0001
DA VF	5 ± 1	4 ± 1	0.0263
DA PEA	7 ± 1	8 ± 2	0.0035

**All variables are presented as the means ± standard deviation. #analysis - number of following heart rhythm analyzes. Abbreviations: ABC - , ACCD - automatic chest compression device, DA PEA - duration of analysis during pulseless electrical activity, DA VF - duration of analysis during ventricular fibrillation, ERC - European Resuscitation Council.*

3.4 Secondary outcomes

ACC paramedic teams inserted SAD earlier. The mean time was 224 ± 66 s for control and 122 ± 35 s for ACC group ($P < 0.0001$).

Moreover, an intravenous line was obtained earlier in ACC when compared to MAN (162 ± 35 vs 183 ± 45).

Mean CCF in MAN group was significantly lower (74 ± 4%) than in ACC one (83 ± 2%) ($P < 0.0001$).

4. Discussion

To our knowledge, this is the first study measuring providers' adherence to resuscitation protocols when providing automated vs. manual CCs.

The risk of a mistakes for providers working under stress and time pressures are high. Making key decisions with limited data is difficult. The 2015 International Liaison Committee on Resuscitation (ILCOR) Consensus on Science reported that there were no studies presenting optimal intervals between rhythm checks.

There is no strong scientific evidence to support the opinion that two-minute interval improves the number of return of spontaneous circulation (ROSC), survival to discharge, increase coronary perfusion pressure (CPP) or cardiac output. On the other hand, it has been estimated that after every two minutes, the quality of CC decreases. ERC recommends that CC should be paused every two minutes to assess the hearth rhythm [2]. Patients with the CCF of 60% and above had the

TABLE 4. Results of deviation time between recommended in ERC protocol and reached by study participants.

*	ERC	MAN [n = 52]	ACC [n = 52]	*P* value#
A1 vs ERC (Δ) [s]	20	10 (5 -13)	3 (0 - 8)	0.0002
A2 vs ERC (Δ) [s]	150	15 (9 - 31)	5 (0 - 10)	< 0.0001
A3 vs ERC (Δ) [s]	280	21 (4 - 60)	8 (0 - 17)	0.0035
A4 vs ERC (Δ) [s]	410	23 (9 - 73)	2 ((-11) - 21)&	0.0003
A5 vs ERC (Δ) [s]	540	14 (1 - 39)	-1 ((-13) - 15)	0.0070
Loop time vs ERC (Δ) [s]	120	18 (14-23)	13 (7 - 17)	0.0003

**all variables are presented in seconds as the medians with interquartile ranges (1^{st} quartile - 3^{rd} quartile); #in the non-parametric Mann-Whitney U test. &negative values indicate that in some scenarios rhythm analyses were earlier than recommended by ERC. Abbreviations: A - analysis, ACC - automatic chest compression group, ERC - European Resuscitation Council, MAN - manual chest compression group.*

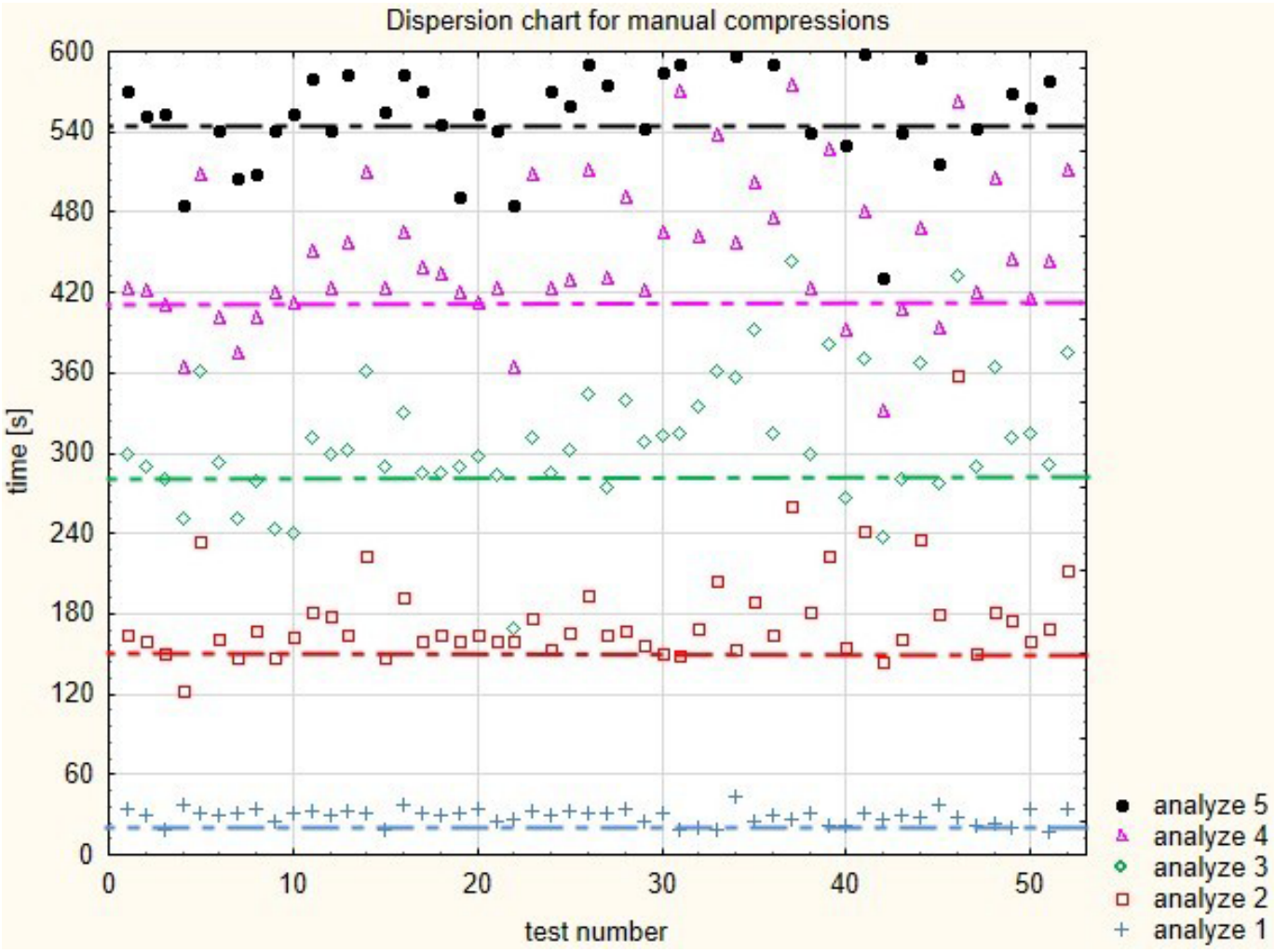

FIGURE 3. Dispersion chart for the control group.

highest chance to survive, with an adjusted OR for survival to the hospital discharge of 1.11 (1.01 to 1.21 5-95th% confidence intervals) per 10% increase in CCF. It has also been found that interruptions in CC for 10 s decreased CPP [18]. In addition, a pre-shock interruption longer than 15 s significantly compromises the outcomes of CPR and increases the risk of severity of post-resuscitation myocardial dysfunction [19].

Interruptions in CC are only allowed during activities that cannot be performed while moving the patient's body [20]. These are: an assessment of heart rhythm, defibrillation and sliding of the endotracheal tube through vocal cords. Bjørshol found that there was not significant extension of noflow time in the first minutes of resuscitation. This problem occurred from the 7^{th} minute onwards [21]. In this study, however, in contrast to ours, CPR was conducted by a three-person team. Additionally, we did not assess the quality by at regular

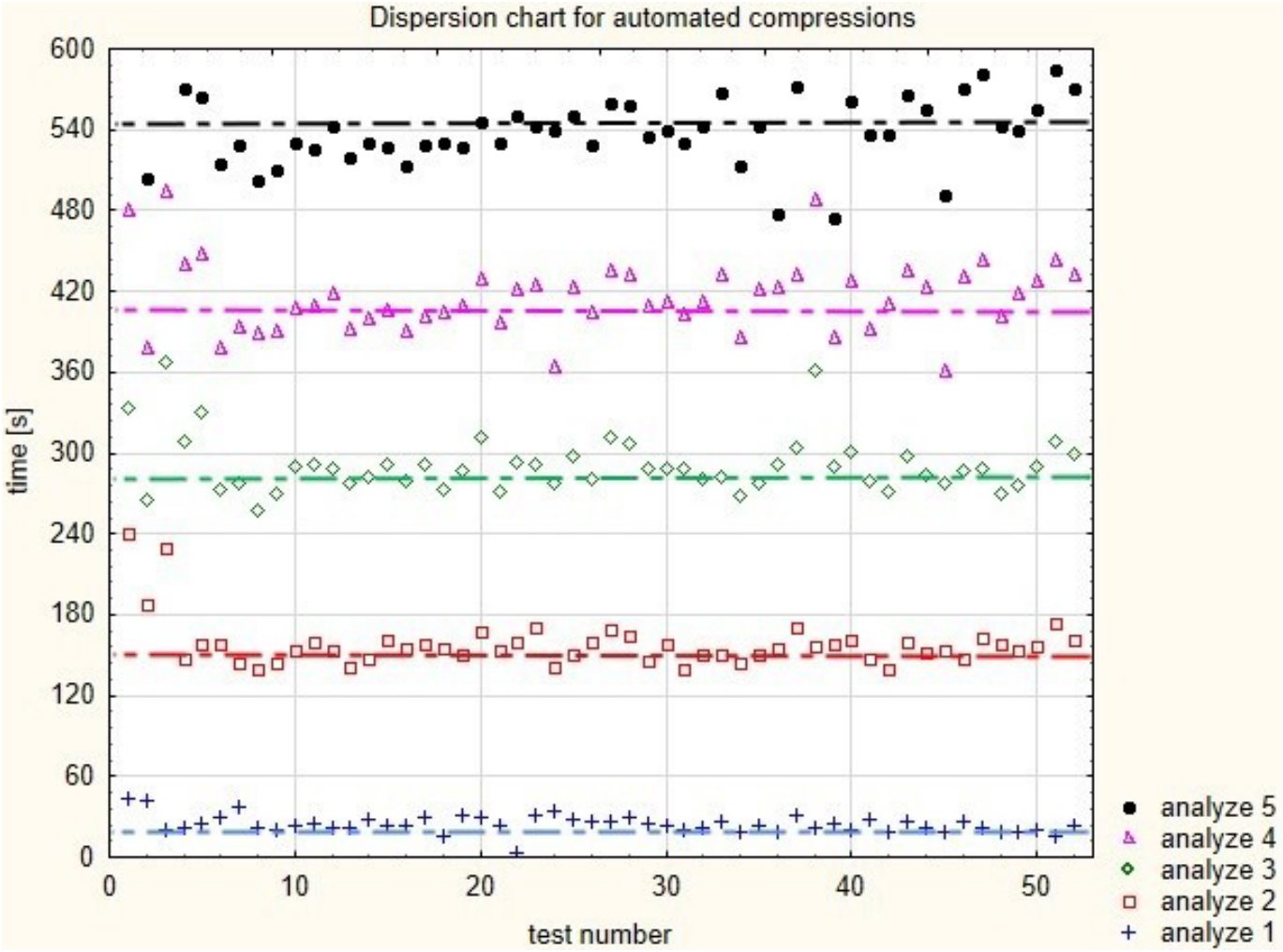

FIGURE 4. Dispersion chart for the experimental group.

intervals of time.

The results presented in this study are in agreement with the ERC. The rhythm assessment was performed in less than 10 seconds, regardless of whether the ACCD was used or not. Previous studies reveal the most common causes of interruptions in CC were due to switching compressors (25%), pulse check (24%), and rhythm analysis (15%) [22]. The possibility of shortening the evaluation time translates directly into shortening of hands-off time. Currently, automatic methods available to assess the rhythm during compression have both high sensitivity (97%) and specificity 99% [23]. This technology, combined with the use of ACCD gives the chance to recognize shockable rhythms and perform defibrillation without any interruption in CC. While it is safe for a rescuer during automated CC, carrying it out during manual CC may harm a rescuer. It can be noticed, that the mean duration of a single resuscitation loop, was longer than it was supposed to be in both groups. However, in ACC, this time was more similar to the one defined in ERC Guidelines. In the latest American publications, some authors suggest that the 2-minute rhythm check is not essential for CC in patients with a non-shockable rhythm [24]. We did not assess the correlation between the duration of the loop and the quality of CPR. Such results have been presented, for example, by Sugerman *et al*. indicating that in 90. second CPR compressions were significantly shallower. While in the case of using ACCD, the quality of each compression is the same, in the manual compressions group, any extension of the loop will result in a deterioration of quality [25].

The difference in SAD insertion time was almost 1.5 minutes. Tomte *et al*. found no significant differences in time of intubation between manual and automated compressions groups [26]. In this research however, teams included emergency medical technicians, paramedics and ambulance physicians. Moreover, scenarios were two-tiered with a second team arriving 5 minutes after the first team. Airway patency is not a priority during resuscitation efforts. Manual maneuvers may be used in the initial phase of the action. However, other advantages of SAD should be considered. It allows providing CC and ventilation asynchronously even when performed by inexperienced medics [27]. This allows for minimizing interruptions associated with ventilation. It should be assumed that faster SAD insertion provides higher CCF value. That suggestion is strongly supported by Sanson *et al*. who found that during asynchronous CPR, higher ventilation rate, CCF, and lower CC rate per minute are delivered [28].

The role of adrenaline in SCA is still being discussed. The ERC 2015 Guidelines recommend adrenaline administration every 3-5 minutes. In non-shockable rhythms, the first dose should be administered as soon as possible. The mean interval

TABLE 5. Intervals between consecutive heart rhythm analyses in seconds.

*	MAN	ACC	*P* value
Interval 1 (A2 - A1)	16 ± 2 [n = 52]#	15 ± 2 [n = 52]	0.0167
Interval 2 (A3 - A2)	29 ± 6 [n = 52]	24 ± 7 [n = 52]	0.8871
Interval 3 (A3 - A2)	177 ± 38 [n = 52]	158 ± 18 [n = 52]	0.0045
Interval 4 (A3 - A2)	311 ± 50 [n = 40]	291 ± 21 [n = 49]	0.2378
Interval A5 - A1	551 ± 36 [n = 40]	538 ± 25 [n = 49]	0.1683
Interval A4 - A1	143 ± 17 [n = 52]	133 ± 11 [n = 52]	0.0012

**All variables are expressed in seconds as the means ± standard deviation. # values within the square brackets indicate how many teams reached a given point of heart rhythm analysis. Abbreviations: A - heart rhythm analysis, ACC - automatic chest compression group, MAN - manual chest compression group.*

between doses in our study was within recommended limits. Adrenaline administered in a 2-minute or shorter interval was associated with a better outcome when compared to longer time to the first dose [29]. Most teams in our study simulations administered adrenaline within the first 5 minutes. Nolan *et al*. found that drug administration is possible 10-20 minutes from incident onset [30]. In this study however, medical records of real events were analyzed and ambulance arrival time was important. It must be stressed that classic ampules and intravenous cannulas were used in our trial. A proper solution may be a routine application of intraosseous access and ready-to-use prefilled adrenaline syringes. However, this is a more expensive strategy.

Advanced procedures and pharmacotherapy are of importance, but they must not overtake high-quality CC. One can speculate that ALS procedures should not be initiated by a two-person team not equipped with ACCD or it should be postponed until a second team support is provided.

Our results suggest that in both groups, some protocol deviations occurred. Other authors imply that this is seen in nearly a half of CPR. McEvoy *et al*. proved that suboptimal timing of the actions, drug administration, omission indicated by ACLS protocol were associated with a lower chance to survive SCA and reach ROSC [12]. Johansson *et al*. found that in out-of-hospital cardiac arrest adherence to guidelines was lower than in-hospital cardiac arrest [31]. In this case, the number of team members in the resuscitation team may play a large role. In many countries, as in Poland, the ambulance is manned by two paramedics. If such a team were to lead the ALS standard resuscitation, a medical compromise should probably need to be used.

There are good quality studies indicating that ACCD can provoke a number of complications. For example, treatment with LUCAS was associated with higher rates of sternal and ribs fracture, severe soft tissue injury, and other serious intrathoracic injuries [32]. All of them may be unfavorable, especially if the patient achieves ROSC. Nevertheless, it should be emphasized that the use of ACCD significantly improved the compliance of the actions with the algorithm. It can be seen in better timing, faster analyzes and overall better adherence to the protocol, which was presented by the ERC experts. In addition, faster implementation of SAD led to increase in CCF, which has been shown to directly increase chances of survival. Taking into account the importance of procedures in current medicine, we think the benefits may outweigh the risks.

5. Limitations

Sudden cardiac arrest is a complex problem. There are many factors influencing survival. CPR should be performed according to an accepted pattern. Although medical simulation is a useful training tool, even high fidelity modeling will never be a complete reflection of real resuscitation scenarios. Performing procedures such as obtaining intravenous lines or SAD may be more time-consuming in real life, because of environmental pressures and working with patients whose anatomy varies. Additionally, participants were aware of taking part in an experiment that could have led to a Hawthorne effect, meaning they were trying to perform CC at their very best. Furthermore, our study included paramedics with a median experience of more than 9 years. We do not know if CC quality in general is different for less experienced, but usually younger paramedics. These aforementioned doubts should warrant further research in this area.

6. Conclusions

The use of ACCD may improve the quality of resuscitation performed in two-paramedic team. This can be achieved

TABLE 6. Time [s] of epinephrine administration, 1^{st}, 2^{nd} and 3^{rd} dose, time interval and IV line implementation.

*	MAN [s]	ACCD [s]	*P*-value
1^{st} dose of epinephrine	272 ± 58	232 ± 57	0.0014
2^{nd} dose of epinephrine	486 ± 96	424 ± 69	0.0007
3^{rd} dose of epinephrine	In 1 scenario	In 4 scenarios	n/a
Time interval[#]	230 ± 54	203 ± 40	0.0128
IV. line placed	183 ± 45	162 ± 35	0.0111

**All variables are presented as the means ± standard deviation. [#]time between consecutive doses of epinephrine. Abbreviations: ACCD - automatic chest compression device, i.v. - intravenous, ACC - automatic chest compression group, MAN - manual chest compression group.*

by improving adherence to ALS protocol, faster adrenaline administration and increasing CCF.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the Institutional Review Board of Poznan University of Medical Sciences (no: KB764/19). Written consent to participate in the study was obtained from each participant.

AUTHOR CONTRIBUTIONS

TK, MP designed the research study. TK, MD performed the research. TK, MP, ŁS, analyzed the data. TK, MP, MD, ŁS wrote the manuscript. MP, BP critically reviewed the manuscript and provided supervision. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

We would like to thank all the peer reviewers and editors for their valuable opinions and suggestions.

CONFLICT OF INTEREST

The authors declare no competing interests.

REFERENCES

[1] Schluep M, Gravesteijn BY, Stolker RJ, Endeman H, Hoeks SE. One-year survival after in-hospital cardiac arrest: a systematic review and meta-analysis. Resuscitation. 2019; 132: 90-100.

[2] Perkins GD, Handley AJ, Koster RW, Castrén M, Smyth MA, Olasveengen T, *et al*. European resuscitation council guidelines for resuscitation 2015 section 2. Adult basic life support and automated external defibrillation. Resuscitation. 2015; 95: 81-99.

[3] Grunau B, Kawano T, Tallon J, Scheuermeyer F, Reynolds J, Besserer F, *et al*. Abstract 344: the association between als response interval and out-of hospital cardiac arrest outcomes. Circulation. 2018; 138: A344.

[4] Vargas M, Buonanno P, Iacovazzo C, Servillo G. Adrenaline for out of hospital cardiac arrest: a systematic review and meta-analysis of randomized controlled trials. Resuscitation. 2019; 136: 54-60.

[5] Dyson K, Bray J, Smith K, Bernard S, Straney L, Finn J. Paramedic exposure to out-of-hospital cardiac arrest is rare and declining in victoria, Australia. Resuscitation. 2016; 89: 93-98.

[6] Kłosiewicz T, Skitek-Adamczak I, Zieliński M. Emergency medical system response time does not affect incidence of return of spontaneous circulation after prehospital resuscitation in one million central European agglomeration residents. Kardiologia Polska. 2017; 75: 240-246.

[7] Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, *et al*. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. Journal of the American Medical Association. 2005; 293: 305-310.

[8] Lugtenberg M, Burgers JS, Westert GP. Effects of evidence-based clinical practice guidelines on quality of care: a systematic review. Quality & Safety in Health Care. 2009; 18: 385-392.

[9] Miller AG, Breslin ME, Pineda LC, Fox JW. An asthma protocol improved adherence to evidence-based guidelines for pediatric subjects with status asthmaticus in the emergency department. Respiratory Care. 2015; 60: 1759-1764.

[10] Wayne DB, Didwania A, Feinglass J, Fudala MJ, Barsuk JH, McGaghie WC. Simulation-based education improves quality of care during cardiac arrest team responses at an academic teaching hospital: a case-control study. Chest. 2008; 133: 56-61.

[11] Ebben RHA, Vloet LCM, Verhofstad MHJ, Meijer S, Mintjes-de Groot JAJ, van Achterberg T. Adherence to guidelines and protocols in the pre-hospital and emergency care setting: a systematic review. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2013; 21: 9.

[12] McEvoy MD, Field LC, Moore HE, Smalley JC, Nietert PJ, Scarbrough SH. The effect of adherence to acls protocols on survival of event in the setting of in-hospital cardiac arrest. Resuscitation. 2014; 85: 82-87.

[13] Cheskes S, Schmicker RH, Rea T, Morrison LJ, Grunau B, Drennan IR, *et al*. The association between AHA CPR quality guideline compliance and clinical outcomes from out-of-hospital cardiac arrest. Resuscitation. 2017; 116: 39-45.

[14] Remino C, Baronio M, Pellegrini N, Aggogeri F, Adamini R. Automatic and manual devices for cardiopulmonary resuscitation: a review. Advances in Mechanical Engineering. 2018; 10: 1-14.

[15] Zhu N, Chen Q, Jiang Z, Liao F, Kou B, Tang H, *et al*. A meta-analysis of the resuscitative effects of mechanical and manual chest compression in out-of-hospital cardiac arrest patients. Critical Care Medicine. 2019; 23: 1-11.

[16] Wang PL, Brooks SC. Mechanical versus manual chest compressions for cardiac arrest. Cochrane Database of Systematic Reviews. 2018; 8: CD007260.

[17] Dabrowski M, Klosiewicz T, Sip M, Zalewski R, Dabrowska A, Wieczorek W, *et al*. The final battle. What more can we do to be victorious with cardiac arrest? Preliminary data. Anestezjologia i Ratownictwo. 2018; 12: 111-116.

[18] Mader T, Coute R, Kellogg A, Harris J, Millay S, Jensen L. Restoring coronary perfusion pressure before defibrillation after chest compression interruptions. Journal of Emergency Medicine. 2014; 2: 29-35.

[19] Yu T, Weil MH, Tang W, Sun S, Klouche K, Povoas H, *et al*. Adverse outcomes of interrupted precordial compression during automated defibrillation. Circulation 2002; 106: 368-372.

[20] Soar J, Nolan JP, Böttiger BW, Perkins GD, Lott C, Carli P, *et al*. European resuscitation council guidelines for resuscitation 2015 section 3. Adult advanced life suport. Resuscitation. 2015; 95: 100-147.

[21] Bjørshol CA, Sunde K, Myklebust H, Assmus J, Søreide E. Decay in chest compression quality due to fatigue is rare during prolonged advanced life support in a manikin model. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2011; 19: 46.

[22] Kessler DO, Peterson DT, Bragg A, Lin Y, Zhong J, Duff J, *et al*. Causes for pauses during simulated pediatric cardiac arrest. Pediatric Critical Care Medicine. 2018; 18: e311-e317.

[23] Fumagalli F, Silver AE, Tan Q, Zaidi N, Ristagno G. Cardiac rhythm analysis during ongoing cardiopulmonary resuscitation using the analysis during compressions with fast reconfirmation technology. Heart Rhythm. 2018; 15: 248-255.

[24] Takegawa R, Shiozaki T, Ohnishi M, Tachino J, Muroya T, Sakai T, *et al*. Abstract 209: the triple CPR 16 study: does rhythm truly needed to be checked every 2 minutes in Cardiopulmonary Arrest Patients? Circulation. 2018; 138: A209.

[25] Sugerman NT, Edelson DP, Leary M, Weidman EK, Herzberg DL, Vanden Hoek TL, *et al*. Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study. Resuscitation. 2009; 80: 981-984.

[26] Tomte O, Sunde K, Lorem T, Weidman EK, Herzberg DL, Vanden Hoek TL, *et al*. Advanced life support performance with manual and mechanical chest compressions in a randomized, multicentre manikin study. Resuscitation. 2009; 80: 1152-1157.

[27] Bielski A, Rivas E, Ruetzler K, Smereka J, Puslecki M, Dabrowski M, *et al*. Comparison of blind intubation via supraglottic airway devices versus standard intubation during different airway emergency scenarios in inexperienced hand. Medicine. 2018; 97: e12593.

[28] Sanson G, Ristagno G, Caggegi GD, Patsoura A, Xu V, Zambon M, *et al*. Impact of 'synchronous' and 'asynchronous' CPR modality on quality bundles and outcome in out-of-hospital cardiac arrest patients. Internal and Emergency Medicine. 2019; 14: 1129-1137.

[29] Bircher NG, Chan PS, Xu Y. Delays in cardiopulmonary resuscitation, defibrillation, and adrenaline administration all decrease survival in in-hospital cardiac arrest. Anesthesiology. 2019; 130 :414-422.

[30] Perkins G, Kenna C, Ji C, Deakin C, Nolan J, Quinn T *et al*. The influence of time to adrenaline administration in the Paramedic 2 randomised controlled trial. Intensive Care Medicine. 2020; 46: 426-436.

[31] Johansson J, Hammerby R, Oldgren J, Rubertsson S, Gedeborg R. Adrenaline administration during cardiopulmonary resuscitation: poor adherence to clinical guidelines. Acta Anaesthesiologica Scandinavica. 2004; 48: 909-913.

[32] Friberg N, Schmidbauer S, Walther Ch, Englund E. Skeletal and soft tissue injuries after manual and mechanical chest compressions. European Heart Journal-Quality of Care and Clinical Outcomes. 2019; 5: 259-265.

How to cite this article: Tomasz Kłosiewicz, Mateusz Puślecki, Łukasz Szarpak, Marek Dąbrowski, Bartłomiej Perek. Automatic compression improves adherence to advanced life support protocol in two-paramedic team. A randomized simulation study. Signa Vitae. 2021;17(1):79-88. doi:10.22514/sv.2020.16.0110.