ORIGINAL ARTICLE

An optimal chest compression technique using personal protective equipment during resuscitation in the COVID-19 pandemic: a randomized crossover simulation study

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KEY WORDS
cardiopulmonary resuscitation, chest compression, coronavirus disease 2019, paramedic

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ABSTRACT

BACKGROUND Cardiopulmonary resuscitation with the use of personal protective equipment (PPE) for aerosol generating procedures (AGP) in patients with suspected or confirmed coronavirus disease 2019 (COVID-19) remains challenging.

AIMS The aim of this study was to compare 3 chest compression (CC) methods used by paramedics wearing PPE.

METHODS The single-blinded, multicenter, randomized, crossover simulation study involved 67 paramedics wearing PPE AGP. They performed 2-minute continuous CCs in an adult with suspected or confirmed COVID-19 in 3 scenarios: 1) manual CCs; 2) CCs with the TrueCPR feedback device; 3) CCs with the LUCAS 3 mechanical CC device.

RESULTS The depth of CC was more frequently correct when using LUCAS 3 compared with TrueCPR and manual CC (median [IQR] 51 [50–55] mm vs 47 [43–52] mm vs 43 [38–46] mm; $P = 0.005$). This was also true for the CC rate (median [IQR]102 [100–102] compressions per minute [CPM] vs 105 [98–1114] CPM vs 116 [112–129] CPM; $P = 0.027$) and chest recoil (median [IQR]100% [98%–100%] vs 83% [60%–92%] vs 39% [25%–50%]; $P = 0.001$). A detailed analysis of 2-minute resuscitation with manual CCs showed a decrease in compression depth and full chest recoil after 1 minute of CCs.

CONCLUSIONS We demonstrated that during simulated resuscitation with the use of PPE AGP in patients with suspected or confirmed COVID-19, CC with LUCAS 3 compared with manual CCs as well as the TrueCPR essentially increased the CC quality. In the case of manual CCs by paramedics dressed in PPE AGP, it is advisable to change the person performing resuscitation every minute.

WHAT'S NEW?

This is the first study to compare manual chest compressions (CCs) in a patient with suspected or confirmed coronavirus disease 2019 with chest compressions performed with the TrueCPR feedback device, as well as with the LUCAS 3 device among paramedics wearing personal protective equipment for aerosol generating procedures. It is worth remembering that during the current severe acute respiratory syndrome coronavirus 2 pandemic, there is a large number of patients with confirmed or suspected infection. We recommend to change the paramedic performing manual continuous CCs every minute if they are wearing personal protective equipment for aerosol generating procedure.

INTRODUCTION

The world, and especially emergency medicine, faces the challenge of fighting the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic.[1,2] The transmission of SARS-CoV-2 is thought to occur mainly through respiratory droplets generated by coughing and sneezing, and through direct contact with contaminated surfaces.[3,4] In view of the above, full personal protective equipment (PPE) for aerosol generating procedures (AGP) must be worn by all members of the emergency medical service team before entering the room.[5,6] There is limited evidence from observational studies showing a protective effect of up to 80% of masks and N95 respirators used by healthcare workers for SARS-CoV viruses.[7] FFP3 respirators should be worn for airborne precautions. In addition, paramedics should also have a visor covering their entire face.

In the case of cardiac arrest, immediate start of resuscitation improves survival.[8] High-quality chest compressions are also of paramount importance for survival and good neurological outcome.[9,10] Unfortunately, even medical personnel often perform chest compressions without achieving the appropriate parameters specified in the guidelines of the European Resuscitation Council (ERC)[11] or the American Heart Association (AHA).[12] Numerous simulation studies indicated too shallow chest compressions, too rapid compression rate, as well as incomplete chest relaxation.[13] No chest compressions or airway procedures such as those detailed below should be undertaken without full PPE AGP. The medical personnel should wear the above equipment before starting intervention in patients with suspected or confirmed coronavirus disease 2019 (COVID-19).[3] However, the use of PPE AGP may make it difficult to perform cardiopulmonary resuscitation (CPR). Therefore, it is advisable to look for alternative modalities of chest compressions which will increase their effectiveness in such patients.

In this context, the objective of this study was to compare 3 chest compression techniques applied by paramedics wearing PPE in simulated resuscitation of a patient with COVID-19: 1) manual, 2) with the TrueCPR feedback device, and 3) with the LUCAS 3 device.

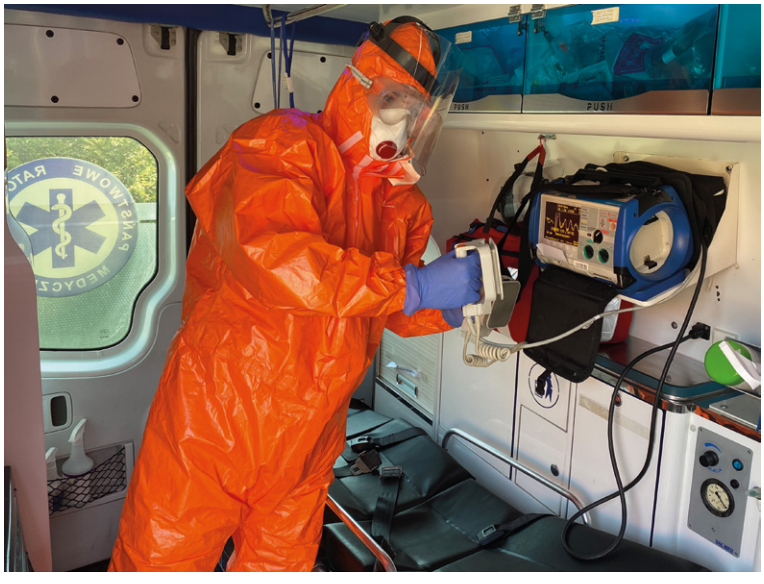

FIGURE 1 Paramedic wearing protective equipment for aerosol generating procedures

METHODS

Setting

Overall, 67 paramedics with no previous experience in resuscitation with PPE were enrolled. All participants signed a voluntary written informed consent prior to the study. Before the evaluation, they underwent training by instructors certified in advanced cardiovascular life support on the usage of the LUCAS 3 device, TrueCPR feedback device, as well as conventional manual CPR in accordance with the 2015 AHA guidelines[12] for 30 minutes. The study was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (no. 04.01.2020.IRB).

Study design

This is a prospective, randomized, crossover simulation study, carried out at the Medical Simulation Centre of Poznan University of Medical Sciences and Lazarski University in Warsaw. On the next day after training, a standardized cardiac arrest scenario was presented to the participants: "You are a member of an emergency medical team and you provide medical assistance to a person quarantined because of a SARS-CoV-2 infection. When you collect the medical history, the patient loses consciousness. The examination shows no pulse or breath. Your colleague performs endotracheal intubation. You need to apply a 2-minute continuous chest compression cycle."

During CPR, paramedics wore the Tychem F chemical-resistant suit, providing protection against organic and inorganic chemicals in high concentrations and against particles below 1 µm in diameter (DuPont Personal Protection, Luxemburg). The suit also protects against biological hazards and against chemical weapon. In order to simulate real-world setting with a patient

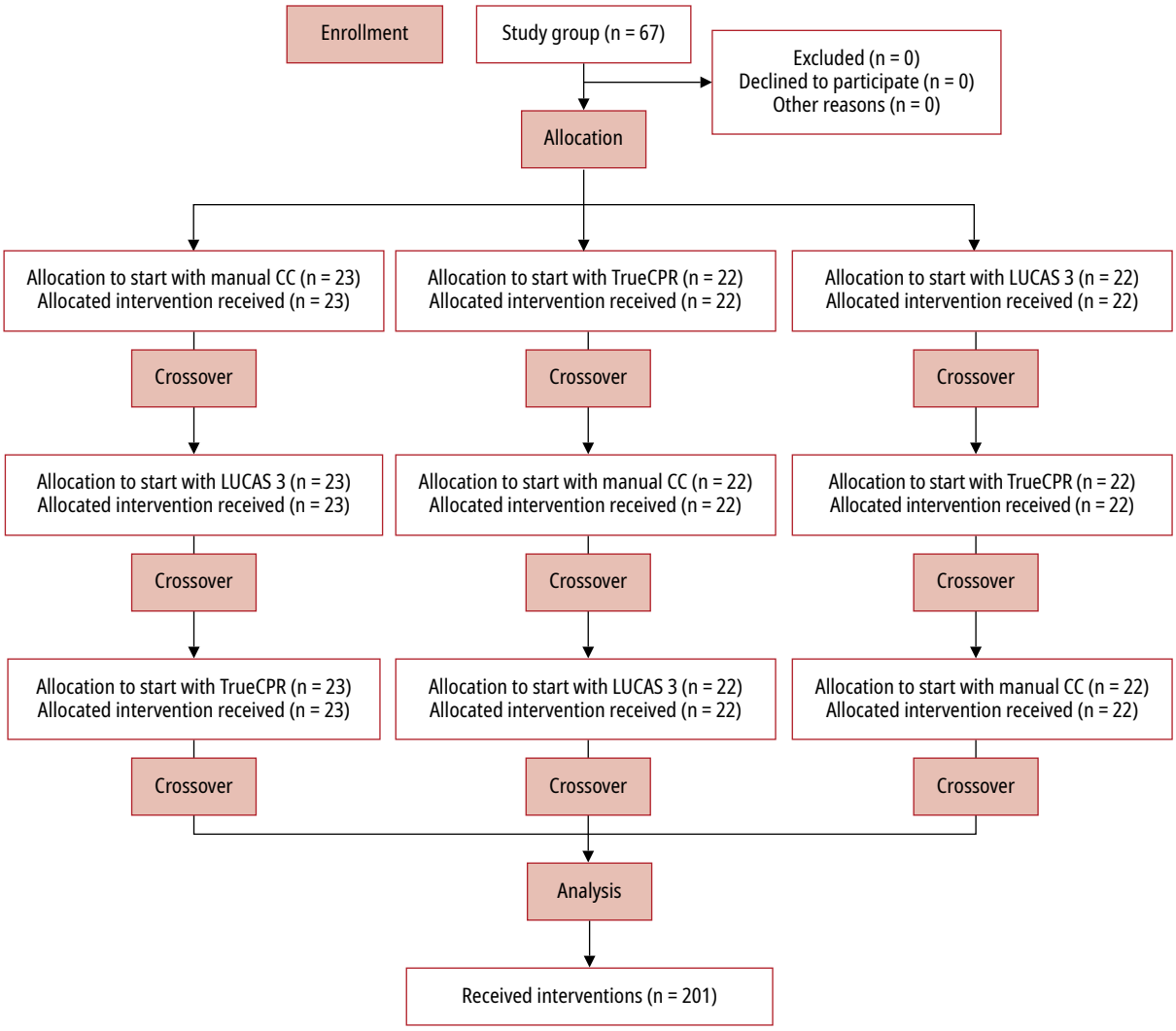

FIGURE 2 The study flowchart
Abbreviations: CC, chest compression

with SARS-CoV-2, paramedics wore a protective mask with FFP1 filter (3M Aura Disposable Respirator, FFP1, Valved, 9312+, 3M Inc., Bracknell, United Kingdom) protective goggles (MedaSEPT, Poznań, Poland), visor, and double nitrile gloves (FIGURE 1). Participants were tested individually.

In the study, the following techniques of chest compressions were tested: 1) manual chest compressions, 2) chest compressions with the TrueCPR feedback device (Physio-Control, Redmond, Washington, United States), 3) chest compressions with the LUCAS 3 mechanical chest compression system (Physio-Control Inc., Lund, Sweden).

A Resusci Anne manikin (Laerdal, Stavanger, Norway) was used to simulate a patient infected with SARS-CoV-2 requiring CPR. Chest compressions were performed continuously for 2 minutes. Both the order of participants and chest compression techniques were random. For this purpose, the Research Randomizer (randomizer.org) was used. The paramedics were divided into 3 groups: the first group started chest compressions with manual chest compressions, the second using the TrueCPR feedback device, and the third applying the LUCAS 3 system. After a 2-minute CPR cycle, the participants had a 1-hour break and then performed CPR with a different technique. Finally, each participant performed chest compressions using all 3 compression modalities tested. A detailed randomization procedure is shown in FIGURE 2.

Data collection Chest compression parameters were assessed with the LLEAP simulation software (Laerdal, Stavanger, Norway) connected to the manikin and included: 1) chest compression depth, 2) chest compression rate, 3) percentage of compressions with correct hand positioning, 4) percentage of full chest recoil.

Additionally, the parameters were recorded in real time with a GoPro Hero 5 Black camera (GoPro, Inc., San Mateo, California, United States), which allowed to register chest compression parameters and analyze them in

TABLE 1 Data from 2-minute chest compression scenarios

Parameter	CC technique			*P* value	Wilcoxon signed-rank test		
	Manual CC (A)	TrueCPR (B)	LUCAS 3 (C)		A vs B	A vs C	B vs C
CC depth, mm	43 (38–46)	47 (43–52)	51 (50–55)	0.005	0.328	0.001	0.451
CC rate, CPM	116 (112–129)	105 (98–114)	102 (100–102)	0.027	0.097	0.001	0.211
Correct chest recoil, %	39 (25–50)	83 (60–92)	100 (98–100)	0.001	<0.001	<0.001	<0.001
Correct hand placement, %	100 (90–100)	100 (93–100)	100 (95–100)	0.225	0.977	0.891	0.772

Parameters are shown as a median (interquartile range) within 2 minutes.

Abbreviations: see FIGURE 2

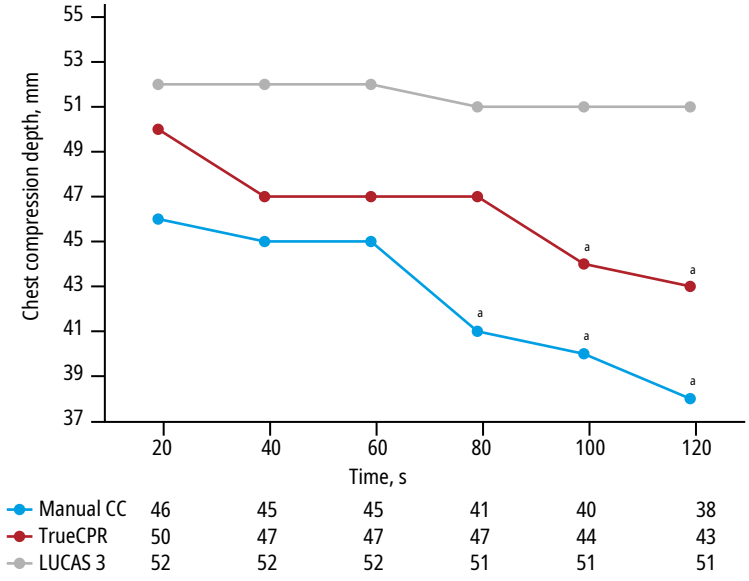

FIGURE 3 Chest compression depth in 20-second intervals

a Statistical significance difference (P <0.05) relative to baseline

Abbreviations: see FIGURE 2

20-second intervals. Goals were set in accordance with the 2015 quality standard established by the ERC: depth of 50 to 60 mm, rate of 100 to 120 compressions per minute (CPM).

Following the completion of a scenario, the participants were asked to grade each chest compression technique on the basis of their fatigue (with 1 indicating no fatigue and 100, extreme fatigue) in the relevant scenario. The demographic data collected included the paramedics' age, gender, and work experience in emergency medicine. The investigators interpreting the results were blinded to the data collected.

Statistical analysis All participant and chest compression parameters were summarized descriptively. Data were analyzed with the Statistica version 13.3EN software (Tibco Inc, Tulsa, Oklahoma, United States). Normal distribution was confirmed by the Kolmogorov–Smirnov test. Categorical data are presented as raw numbers and frequencies, and continuous and ordinal data are presented as medians and interquartile ranges (IQR). The Friedman test was used for the intra-group analysis, and the Wilcoxon signed-rank test for the pairwise comparison. A P value of less than 0.05 was considered statistically significant and the significance level was adjusted using the Bonferroni correction for multiple comparisons for the post hoc analysis. The median changes during 20-second epochs were tested using the Wilcoxon signed rank test.

RESULTS A total of 67 paramedics (women, 25 [37.3%]) participated in the study. Their median (IQR) age was 30 (27–33) years, and median (IQR) work experience time was 4.1 (2–7) years.

Chest compression quality The median (IQR) chest compression depth when using different chest compression techniques varied and equaled 43 mm (38–46) mm vs 47 (43–52) mm vs 51 (50–55) mm (P = 0.005; TABLE 1) for manual chest compressions, TrueCPR, and LUCAS 3, respectively. There was a difference between the compressions with LUCAS 3 and manual compressions (P <0.001), as well as between compressions with LUCAS 3 and TrueCPR (P = 0.021). The median (IQR) chest compression rate was 116 (112–129) CPM for the manual technique, 105 (98–114) CPM with TrueCPR, and 102 (100–102) CPM with LUCAS 3 (P = 0.027). Moreover, significant differences between manual chest compressions and LUCAS 3 were noted (P <0.001).

The median (IQR) percentage of correct chest recoil with manual chest compressions was 39% (25%–50%), 83% (60%–92%) for TrueCPR, and 100% (98%–100%) for LUCAS 3. The analysis showed differences in correct chest recoil between manual compressions and TrueCPR (P <0.001), manual compressions and LUCAS 3 (P <0.001), as well as TrueCPR and LUCAS 3 (P = 0.033).

The median (IQR) correct hand placement was comparable in the examined chest compression techniques and equaled 100% (90%–100%) for

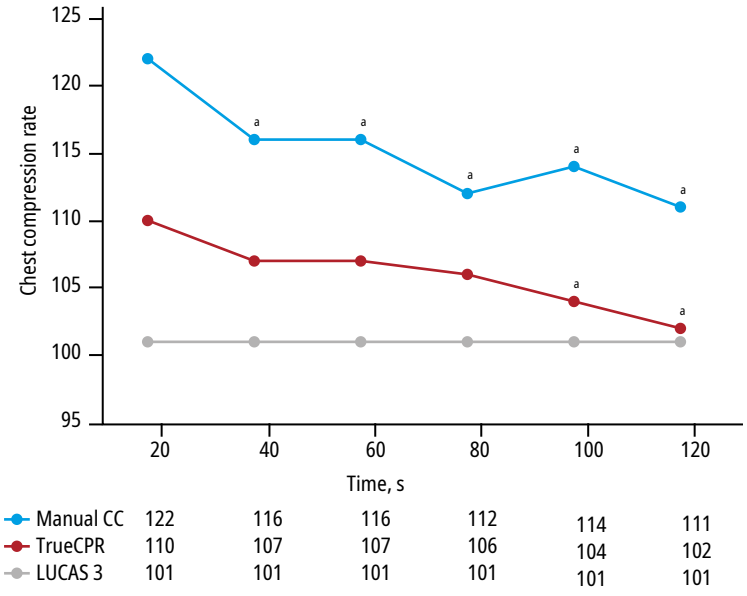

FIGURE 4 Chest compression rate in 20-second intervals

a Statistical significance difference (P <0.05) relative to baseline

Abbreviations: see FIGURE 2

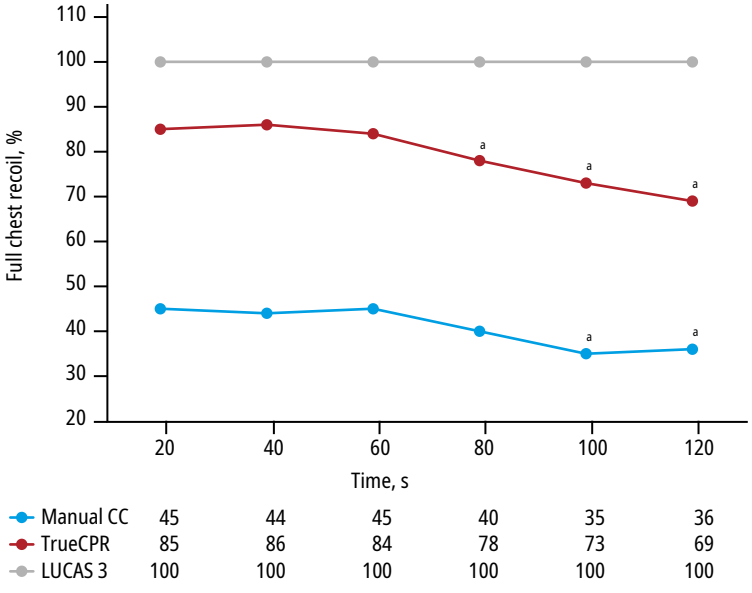

FIGURE 5 Percentage of correct chest recoil in 20-second intervals

a Statistical significance difference (P <0.05) relative to baseline

Abbreviations: see FIGURE 2

manual compressions, 100% (93%–100%) for TrueCPR, and 100% (95%–100%) for LUCAS 3.

The analysis of 20-second intervals showed a significant decrease in chest compression depth in manual chest compressions (FIGURE 3). When TrueCPR was used during CPR, a significant reduction in chest compression depth was observed from 80 seconds onwards. The analysis of the data for 20-second time periods showed no differences when using LUCAS 3. However, differences in the rate of chest compressions during the 2-minute chest compression period were observed in manual compressions and TrueCPR (FIGURE 4). The percentage of correctly performed chest recoil was the lowest for the manual technique and decreased over time as the chest compressions were performed, starting from the first minute of compressions (FIGURE 5).

Subjective rescuer fatigue All participants completed all three 2-minute continuous resuscitation sessions. Self-reported levels of fatigue for each chest compression modality are presented in TABLE 2.

DISCUSSION

To the best of our knowledge, this is the first study to compare manual chest compressions in a patient with suspected or confirmed COVID-19 and chest compressions performed with the TrueCPR feedback device and the LUCAS 3 device among paramedics wearing PPE AGP. This is of importance during the current SARS-CoV-2 pandemic, as there area large numbers of patients infected with or suspected of SARS-CoV-2.

For safety reasons, both for the rescuers themselves and for the patients requiring chest compressions or airway procedures, CPR should be undertaken with full PPE AGP. As indicated by Li et al,[14] the population most at risk may be people with poor immune function, such as the elderly and those with renal or hepatic dysfunction. Mortality is highest in the group over 60 years of age. This is due to the coexistence of associated diseases. Often, in a patient infected with SARS-CoV-2, sudden cardiac arrest occurs for a completely different reason, and undertaking CPR may cause return of spontaneous circulation.

TABLE 2 Level of fatigue during each trial based on a Likert scale rating

Parameter	Chest compression technique			*P* value	Wilcoxon signed-rank test		
	Manual CC (A)	TrueCPR (B)	LUCAS 3 (C)		A vs B	A vs C	B vs C
Participants' perception of fatigue (1–100)	70 (50–86)	70 (45–82)	17 (10–20)	0.001	0.72	<0.001	<0.001

Data are shown as median (interquartile range).

Abbreviations: see FIGURE 2

The ability to perform high quality CPR is an important element of the management of patients with sudden cardiac arrest, directly affecting survival and reducing neurological losses.[15,16] The algorithms to be applied by the medical personnel are the guidelines by the ERC[11] or the AHA,[12] following the principles of evidence-based medicine. According to those guidelines, chest compressions should be carried out with the following parameters: depth of compressions of 5 to 6 cm and rate of chest compressions of 100 to 120 CPM. In addition, full chest relaxation should be performed, as well as interruptions in chest compressions should be minimized.[12]

In this study, we prospectively assessed differences in chest compression techniques applied by paramedics wearing PPE AGP in simulated resuscitation of a patient with COVID-19. During simulated resuscitation, chest compressions with LUCAS 3 compared with manual chest compressions as well as the TrueCPR feedback device essentially increased chest compression quality. We demonstrated, for instance, that the depth of chest compressions during manual CPR was insufficient. This result is consistent with other studies and applies to paramedics, physicians, and nurses.[17,18] Moreover, it was shown that the depth of chest compressions performed by paramedics dressed in PPE AGP was significantly reduced after the first minute of intervention.

Taking into account the CPR guidelines with regard to changes of rescuers in 2-minute cycles,[19,20] it is reasonable to consider introducing a reduction of a CPR cycle duration from 2 to 1 minute in the CPR algorithms for patients with suspected or confirmed COVID-19. Of note, Kılıç et al[21] have reported that there was no difference in the quality measures of chest compressions between 1- and 2-minute cycles in a normal scenario (without PPE AGP).

Another important factor influencing the quality of chest compressions is the compression rate.[22,23] In our study, the participants performed compressions at a correct rate; however, the parameter differed between the modalities. The most constant rate was observed for the LUCAS 3 device, and the rate with manual compressions was the fastest. The guidelines recommend chest compressions at a rate of 100 to 120 CPM. As is indicated in the AHA and ERC guidelines, there is a positive correlation between the number of compressions delivered per minute and success of resuscitation, and rates of 120/min or higher or less than 100/min are associated with a decreased likelihood of survival. Also, a study by Idris et al[24] confirmed that compression rates of 100 to 120 CPM are associated with greatest survival to hospital discharge. As revealed by Chen at al,[25] the use of PPE may reduce the rate of chest compressions. The compression rate greater than 120 CPM may improve organ perfusion but does not increase survival to hospital discharge. In turn, the rescuer may become tired faster, which may result in lower quality of chest compressions.[26,27]

Full chest recoil also improves survival and has favorable neurologic outcomes.[28] Full chest relaxation combined with chest compressions at an appropriate depth are essential for optimal perfusion pressure.[29,30] Lee et al[31] showed significantly more incomplete chest recoils at the rate of over 120 CPM than at any other rate. In the study, the percentage of full chest recoil was insufficient for manual compressions. Numerous studies also indicated that CPR feedback devices can improve chest compression quality.[32-35] Buléon et al[17] demonstrated that a real-time feedback device provided longer, effective, steadier chest compressions over time; however, as the presented study revealed, the depth parameters of chest compressions using the device were higher than those of manual compressions, but still insufficient in relation to the current CPR guidelines.[19,36]

This may be due to excessive fatigue of the rescuers, which seems to be confirmed by Rodríguez et al,[37] who evidenced that CPR required intensive physical effort while wearing a level D PPE. Nowadays, more and more emergency teams are equipped with mechanical chest compression systems that allow for high-quality chest compressions also during transport to the hospital.[38] It is noteworthy that automatic chest compression devices are not recommended for a routine use during resuscitation.[39] However, it should be assumed that resuscitation of patients with suspected or confirmed COVID-19 is not a routine procedure, and PPE AGP reduces the motoric capacity and causes overheating and increased fatigue.[40-42]

Limitations Our study has both limitations and strengths. First, the study was conducted with simulated, rather than real, CPR; however, this was deliberate because medical simulation allows full standardization of medical procedures.[43,44] Moreover, in the current sitation related to the SARS-CoV-2 pandemic, this type of tests are not allowed because they could prolong the time of the performed procedures and expose the patient's and paramedic's health to harm.[45] The second limitation was that we only included paramedics; however, it is this professional group that may realistically face a situation requiring CPR, including a patient with suspected or confirmed COVID-19. The paramedics themselves, in prehospital conditions, can only rely on their skills and equipment available in the ambulance. The third limitation regards lack of previous experience in performing CPR in a PPE AGP; however, this was also deliberate. The current pandemic poses a global threat to medical personnel and leads to the need to use

PPE AGP. Most of the medical personnel (both in the hospital and prehospital setting) were not concerned with the use of PPE AGP. In view of the above, it was decided to select paramedics who constitute a specific group of healthcare professionals in contact with patients who experience out-of-hospital cardiac arrest.

The strengths of the study should also be indicated. This was a multicenter randomized crossover study. Moreover, it was the first study to evaluate the resuscitation capacities of paramedics wearing PPE AGP.

Conclusions During resuscitation in simulated patients with suspected or confirmed COVID-19 performed by paramedics wearing PPE AGP, chest compression with LUCAS 3 compared with the manual technique as well as the TrueCPR feedback device increased the compression quality. In the case of manual chest compressions performed by paramedics dressed in PPE AGP, it is advisable to change the rescuer every 1 minute.

ARTICLE INFORMATION

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CONTRIBUTION STATEMENT All authors confirm that they had full access to data, contributed to drafting the paper, analyzed the data, edited the paper and approved the final version of the manuscript. MM and ŁSZ designed and coordinated the study.

CONFLICT OF INTEREST None declared.

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