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Effects of the Cardio First Angel™ on chest compression performance

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Abstract.
BACKGROUND: Survival rates of out-of-hospital cardiac arrest remain poor. Bystander cardiopulmonary resuscitation (CPR) is crucial for survival and feedback devices could improve its quality.
OBJECTIVE: We investigated the quality of chest compression when using the Cardio First Angel™ (CFA) feedback device compared to standard basic life support (BLS). The analysis focused on laymen.
METHODS: Laymen without ($n = 43$) and with ($n = 96$) explanation of the device, medical students ($n = 128$) and medical staff ($n = 27$) performed 60 seconds of standard versus assisted chest compression using the CFA on a resuscitation manikin. Compression frequency, depth and position were analyzed according to current guidelines.
RESULTS: Laymen showed significantly better success rates regarding correct compression depth when using the CFA (23.3% vs. 55.8%, $p = 0.004$ and 25.0% vs. 52.1%, $p < 0.001$, laymen without and with explanation of the device, respectively). Medical students likewise improved (22.7% vs. 42.2%, $p = 0.004$). Hand positioning was 100% correct in all groups with the device. Improvement in frequency yielded by the CFA was more pronounced for probands with fears of contact ($p = 0.02$). The benefit of using the device did not differ significantly in laymen with or without explanation.
CONCLUSIONS: Chest compression as performed by laymen was significantly improved with regard to compression depth when using the CFA for guidance and feedback. With the device, no cases of incorrect hand positioning occurred in any group.

Keywords: Cardiopulmonary resuscitation, cardiac arrest, chest compression, CPR quality, Cardio First Angel™

1. Introduction

Out-of-hospital cardiac arrest affects 20.9–186.0 patients/100.000/year and survival rates remain poor [1–3]. Global morbidity as well as mortality are immense and socioeconomic impact is high [2,4]. As first response measures, established guidelines and current analyses highlight the importance of recognizing cardiac arrest early, promptly placing the emergency call, performing cardiopulmonary resuscitation (CPR) and defibrillation [1,5,6]. Even though randomized trials in this specific setting are hardly

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Fig. 1. Cardio First Angel™ device.

feasible and corresponding data are thus lacking, studies indicate that bystander CPR performed before the arrival of emergency medical services (EMS) is associated with profoundly increased survival rates and similarly, associations between the time from collapse to start of CPR and survival have been emphasized [1,5].

Whilst the role of bystanders is thus widely deemed crucial, the knowledge, skills and confidence of the latter will vary according to the circumstances, level of training and prior experience [6]. Furthermore, even though CPR trainings are offered widely spread, performance especially of laymen deteriorates soon after training [7]. Adjunct devices assisting and guiding bystanders could potentially improve CPR performance. The Cardio First Angel™ (Cardio First Angel UG, Munich, Germany/INOTECH, Nubberg, Germany) device was recently shown to be associated with beneficial clinical results when being used in an intensive care unit setting [8]. Here, we focus on laymen and examine performance in chest compression comparing usage of the Cardio First Angel™ device to standard basic life support (BLS).

2. Methods

2.1. Cardio First Angel™ device

The Cardio First Angel™ (Fig. 1) is a commercially available mechanical resuscitation device to assist in chest compression. It is totally manually-operated and does not require an electrical power source. It is a compact and light-weight device which is placed on the patient's chest (Fig. 2). Its drop-shape shall optimize device-positioning whereas the triangular part is orientated towards the caudal sternum and the rib bows. The user places the hands on the device and applies compression as in conventional CPR which is transmitted onto the patient's thorax via the device. Due to special springs in the core of the device, the resuscitator is provided with a mechanically generated feedback click-sound that, according to the manufacturer, arises as soon as sufficient compression (equalizing 50–60 mm compression depth) has been created. Another click-sound results after complete decompression. Furthermore, the clicking is supposed to help the user in achieving an ideal compression frequency. On the top-part, three numbered pictograms are provided, indicating to bare the patient's chest, where to position the device and

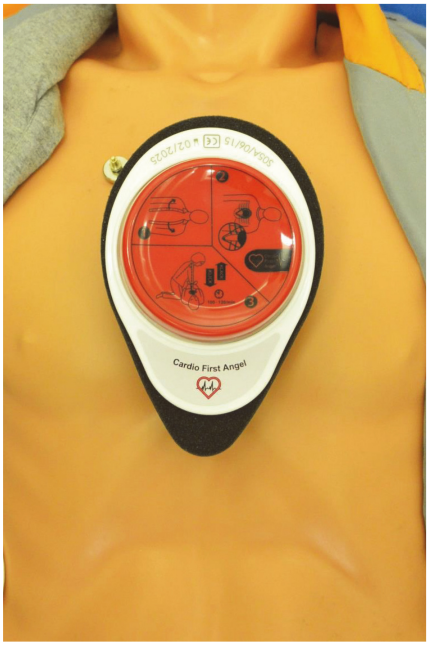

Fig. 2. Positioning of the Cardio First Angel™ device.

how to perform chest compression including the reference frequency of 100–120/min and the acoustic feedback. The device is designed for out-of-hospital laymen CPR but may also assist healthcare professionals, especially in the initial phase of resuscitation until specialized rapid response teams with profound training and dedicated equipment arrive.

2.2. *Study design and protocol*

The study was designed as a crossover trial with four study groups in order to evaluate potential differential effects of the device depending on an individual's previous knowledge and skills regarding chest compression. Performance in chest compression when using the Cardio First Angel™ device was compared to standard basic life support (BLS).

The first group ($n = 43$) consisted of laymen randomly recruited in the central city of Munich during one day. The subjects of the second group were recruited similarly (one day, $n = 96$) but additionally given a standardized brief explanation of the device covering the pictograms, device-positioning and implications of the acoustic feedback. We included a group of laymen without and another with introduction into the device in order to examine the self-explanatory characteristics of the device. The third group consisted of medical students of the Ludwig-Maximilian-University Munich who had successfully completed curricular basic and advanced life support (ALS) training ($n = 128$, recruited within two days). For the fourth group, medical staff members were recruited ($n = 27$, recruited within one day). In total, 294 subjects participated in the study.

After consenting to participate in the study, all participants were asked to perform two cycles of chest compression on an Ambu® Man Torso (Ambu A/S, Ballerup, Denmark) CPR manikin. Each cycle comprised 60 seconds whereas a signal was given to indicate both, start and end of the time span. The first cycle was performed as standard BLS according to the individual state of knowledge of

the participant without any further assistance. The second cycle was performed using the Cardio First Angel™. In between the two cycles a break to allow for sufficient recovery was given. Besides the group with explicit instruction, no explanation of the device was provided. The group with explanation of the device received the latter after having completed the conventional BLS cycle.

Chest compression performance was registered and analyzed with regard to frequency (reference range 100–120/min), depth (50–60 mm) and position (center of the chest, i.e. on the lower half of the sternum) according to the European Resuscitation Council (ERC) Guidelines for Resuscitation 2015 using the Ambu® CPR Software, Version 3.1.1 [6]. Data were extracted for statistical analysis.

In order to obtain a subjective assessment, participants were asked to complete a questionnaire after having performed chest compression. The questionnaire investigated general willingness to perform CPR (yes/no), asked for a self-assessment of CPR skills regarding successful resuscitation (scale from 0 = lowest to 10 = highest option), checked for fears of contact (yes/no, if yes regarding physical contact/blood/body fluids, infection or unsuccessful resuscitation), asked whether the participant would use a device that assists regarding compression strength, frequency and finding the correct hand position (yes/no) and whether the participant would rather use the hands or the device (Cardio First Angel™) for resuscitation. Additionally, participants were asked to provide their age ($<$ 18 years, 18–30 years, 31–40 years, 41–50 years, 51–60 years, 61–70 years, $>$ 70 years) and gender (female/male). Lastly, participants were asked if they had participated in a first aid course before (yes/no), if they would use the Cardio First Angel™ device (yes/no), whether they would be willing to spend money for the device and in case yes how much (no/yes, if yes amount of money in Euro).

All participants volunteered for the study. The study was approved by the institutional ethics' committee.

2.3. Statistical analysis

Compression depth measurements were averaged for each participant. Data outside the reference ranges were considered incorrect. Categorical variables are presented as absolute numbers and percentages, and continuous variables as mean ± standard deviation (SD). Boxplots are used to represent continuous variables. Comparisons of success rates (conventional chest compression versus Cardio First Angel™ device) were performed using the McNemar test. Confidence intervals for rates were computed using the standard method by Clopper and Pearson implemented as a default in the R function 'binom.test'. To assess the differences between the effects of the Cardio First Angel™ device on different groups, the generalized estimating equations (GEE) method (as implemented in the R package 'geepack') was used to fit models with the success as binary outcome and the considered group and the method (conventional chest compression versus Cardio First Angel™ device) as well as their interaction as covariates. Probands were considered as units and an exchangeable correlation structure was assumed within probands for GEE estimation. The Wald test was used to assess the interaction effect between group and method. All tests were performed at the level $\alpha = 0.05$. Statistical analyses were performed by a biostatistician at our institution using the R program for statistical computing (version 3.2.0).

3. Results

Altogether, 294 subjects participated in the study. Due to organizational difficulties, $n = 46$ medical students did not answer the questionnaire (i.e., $n = 82$ with completed questionnaire). Demographic data are depicted in Table 1. Table 2 provides detailed results of the remaining items asked for in the

Table 1
Demographic characteristics of the study participants. Only medical students that completed the questionnaire are considered in the table ($n = 82$)

	Laymen without explanation of the device	Laymen with explanation of the device	Medical students	Medical staff
n	43	96	82	27
Female, n (%)	28 (65.1%)	47 (49.0%)	43 (52.4%)	16 (59.3%)
Age				
$<$ 18 years, n (%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
18–30 years, n (%)	16 (37.2%)	35 (36.5%)	76 (92.7%)	19 (70.4%)
31–40 years, n (%)	6 (14.0%)	19 (19.8%)	4 (4.9%)	5 (18.5%)
41–50 years, n (%)	5 (11.6%)	24 (25.0%)	1 (1.2%)	1 (3.7%)
51–60 years, n (%)	5 (11.6%)	9 (9.4%)	1 (1.2%)	2 (7.4%)
61–70 years, n (%)	6 (14.0%)	7 (7.3%)	0 (0%)	0 (0%)
$>$ 70 years, n (%)	5 (11.6%)	2 (2.1%)	0 (0%)	0 (0%)

n number.

Table 2
Questionnaire results. Only medical students that completed the questionnaire are considered in the table ($n = 82$)

	Laymen without explanation of the device	Laymen with explanation of the device	Medical students	Medical staff
n	43	96	82	27
General willingness to perform CPR, n (%)	40 (93.0%)	93 (96.9%)	79 (96.3%)	26 (96.3%)
Self-assessment of CPR skills				
0, n (%)	0 (0%)	2 (2.1%)	0 (0%)	0 (0%)
1, n (%)	0 (0%)	1 (1.0%)	2 (2.4%)	0 (0%)
2, n (%)	0 (0%)	4 (4.2%)	0 (0%)	4 (14.8%)
3, n (%)	7 (16.3%)	7 (7.3%)	3 (3.7%)	0 (0%)
4, n (%)	5 (11.6%)	16 (16.7%)	11 (13.4%)	1 (3.7%)
5, n (%)	10 (23.3%)	28 (29.2%)	14 (17.1%)	3 (11.1%)
6, n (%)	8 (18.6%)	10 (10.4%)	7 (8.5%)	3 (11.1%)
7, n (%)	3 (7.0%)	17 (17.7%)	25 (30.5%)	4 (14.8%)
8, n (%)	8 (18.6%)	6 (6.2%)	14 (17.1%)	5 (18.5%)
9, n (%)	1 (2.3%)	2 (2.1%)	5 (6.1%)	3 (11.1%)
10, n (%)	1 (2.3%)	3 (3.1%)	1 (1.2%)	4 (14.8%)
Fears of contact, n (%)	15 (34.9%)	37 (38.5%)	30 (36.6%)	5 (18.5%)
Fear of				
physical contact/blood/body fluids, n (%)	9 (20.9%)	21 (21.9%)	10 (12.2%)	3 (11.1%)
infection, n (%)	6 (14.0%)	10 (10.4%)	14 (17.1%)	2 (7.4%)
unsuccessful resuscitation, n (%)	10 (23.3%)	25 (26.0%)	13 (15.9%)	2 (7.4%)
Would generally use an assisting device, n (%)	36 (83.7%)	92 (95.8%)	73 (89.0%)	25 (92.6%)
Would resuscitate using rather				
hands, n (%)	7 (16.3%)	26 (27.1%)	40 (48.8%)	10 (37.0%)
device (Cardio First Angel™), n (%)	36 (83.7%)	70 (72.9%)	42 (51.2%)	17 (63.0%)
Had participated in first aid course before, n (%)	35 (81.4%)	87 (90.6%)	81 (98.8%)	25 (92.6%)
Would use Cardio First Angel™ device, n (%)	42 (97.7%)	83 (86.5%)	57 (69.5%)	22 (81.5%)
Would be willing to spend money for the device, n (%)	41 (95.3%)	63 (65.6%)	30 (36.6%)	18 (66.7%)
Amount [Euro], mean $\pm$ SD	48.0 $\pm$ 49.8	30.8 $\pm$ 23.5	25.4 $\pm$ 19.9	37.8 $\pm$ 36.8

n number, *CPR* cardiopulmonary resuscitation, *SD* standard deviation.

questionnaire. General willingness to perform CPR was high throughout all groups and by far exceeded 90%. The majority of laymen (without respectively with explanation of the device) ranked their own resuscitation skills as being on an intermediate level (76.8% and 81.3% within the range from 3 to 7,

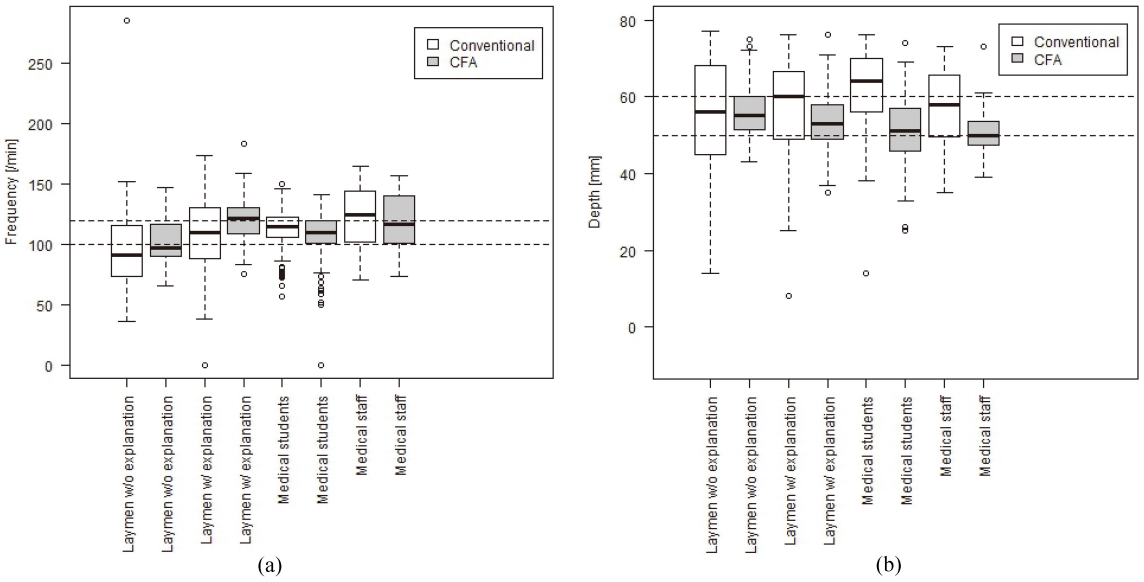

Fig. 3. Compression frequency and depth during conventional cardiopulmonary resuscitation and resuscitation using the Cardio First Angel^{TM} device. Interquartile range (box), median (band), extreme data points within 1.5 times the interquartile range (whiskers) and outliers (circles). The reference range is indicated via dashed lines. *CFA* Cardio First Angel^{TM}, $w/$ with, w/o without.

respectively). The vast majority of subjects had participated in a first aid course before (81.4% and 90.6% of laymen, 98.8% of medical students and 92.6% of medical staff, respectively). Interestingly, a substantial proportion of all groups expressed fears of contact. This included medical professionals, even though the percentage in this group was only 18.5% and thus lower than the percentages within the other groups all of which exceeded one third.

Performing conventional chest compression according to the individual state of knowledge of the participant in comparison to using the Cardio First Angel^{TM} did not show any significant differences regarding correctness of compression frequency for all groups. Of note, proportions of participants with correct compression frequency were low throughout all groups. Medical students represented the only group with more than 50% of the subjects achieving correct compression frequencies within the reference range of 100–120/min. Compression frequency results of all groups during conventional chest compression and when using the Cardio First Angel^{TM} are illustrated in Fig. 3a. Both, laymen without and with explanation of the device showed a significantly better success rate regarding correct compression depth when using the Cardio First Angel^{TM} device (23.3% vs. 55.8%, $p = 0.004$ and 25.0% vs. 52.1%, $p < 0.001$, respectively). Similarly, positive effects were observed for medical students (22.7% vs. 42.2%, $p = 0.004$) while no effect was seen in medical staff ($p = 0.39$). For detailed results of compression depth see Table 3 and Fig. 3b. Neither age nor sex were significantly associated with the effect of using the Cardio First Angel^{TM} device versus conventional chest compression ($p > 0.05$ for both, frequency and depth, Wald test for interaction effect in GEE). Furthermore, the benefit of using the Cardio First Angel^{TM} device did not differ significantly in laymen with or without explanation. The improvement yielded by usage of the Cardio First Angel^{TM} versus conventional chest compression regarding frequency was significantly higher for probands with fears of contact in general and for probands with fear of physical contact/blood/body fluids, respectively ($p = 0.02$ and $p = 0.03$; Wald test for interaction effect in GEE model with adjustment for group). All other test results concerning fears were non-significant.

Table 3
Chest compression performance parameters during conventional cardiopulmonary resuscitation and resuscitation using the Cardio First Angel™ device. p-value: McNemar test

	Laymen without explanation of the device			Laymen with explanation of the device			Medical students			Medical staff		
n	43			96			128			27		
	Conventional	*CFA*	*p*	*Conventional*	*CFA*	*p*	*Conventional*	*CFA*	*p*	*Conventional*	*CFA*	*p*
Frequency												
Mean ± SD [/min]	95.9 ± 40.3	101.8 ± 18.7		105.1 ± 32.6	120.6 ± 17.9		112.7 ± 17.1	107.2 ± 19.5		122.0 ± 25.7	118.7 ± 23.7	
Too slow (< 100/min)												
n	27	23		36	8		24	28		6	7	
%	62.8%	53.5%		37.5%	8.3%		18.8%	21.9%		22.2%	25.9%	
Too fast (> 120/min)												
n	7	9		33	50		39	27		15	13	
%	16.3%	20.9%		34.4%	52.1%		30.5%	21.1%		55.6%	48.1%	
Correct (100–120/min)												
n	9	11		27	38		65	73		6	7	
%	20.9%	25.6%	0.79	28.1%	39.6%	0.13	50.8%	57.0%	0.19	22.2%	25.9%	1.00
CI	10.0–36.0%	13.5–41.2%		19.4–38.2%	29.7–50.1%		41.8–59.7%	48.0–65.7%		8.6–42.3%	11.1–46.3%	
Depth												
Mean ± SD [mm]	54.5 ± 16.8	57.0 ± 9.0		57.4 ± 13.2	53.6 ± 7.7		62.0 ± 10.7	51.4 ± 8.3		57.3 ± 10.5	50.8 ± 7.1	
Too shallow (< 50 mm)												
n	16	9		25	27		19	56		7	12	
%	37.2%	20.9%		26.0%	28.1%		14.8%	43.8%		25.9%	44.4%	
Too deep (>60 mm)												
n	17	10		47	19		80	18		12	3	
%	39.5%	23.3%		49.0%	19.8%		62.5%	14.1%		44.4%	11.1%	
Correct (50–60 mm)												
n	10	24		24	50		29	54		8	12	
%	23.3%	55.8%	0.004	25.0%	52.1%	< 0.001	22.7%	42.2%	0.004	29.6%	44.4%	0.39
CI	11.8–38.6%	39.9–70.9%		16.7–34.9%	41.6–62.4%		15.7–30.9%	33.5–51.2%		13.8–50.2%	25.5–64.7%	
Position												
Correct												
n	33	43		79	96		122	128		25	27	
%	76.7%	100%	n.a.	82.3%	100%	n.a.	95.3%	100%	n.a.	92.6%	100%	n.a.
CI	61.4–88.2%	n.a.		73.2–89.3%	n.a.		90.1–98.3%	n.a.		75.7–99.1%	n.a.	

n number, *CFA* Cardio First Angel™, *SD* standard deviation, *CI* 95% confidence interval.

Even though rates of correct hand positioning were high throughout all groups during conventional chest compression (ranging from 76.7% to 95.3%), when using the Cardio First Angel™ correctness of position was 100% in all groups, i.e. no mistakes in hand positioning occurred when using the device. Detailed data on chest compression performance are given in Table 3.

A broad majority of the participants stated that they would use a device that assists regarding compression strength, frequency and locating the correct position (83.7–95.8% for the different groups, respectively). Approval of the Cardio First Angel™ device in particular was likewise high among laymen and medical staff (81.5–97.7%). 69.5% of the medical students stated that they would use the device. Especially laymen would resuscitate rather using the device than conventionally performing CPR by hand only (83.7% and 72.9%, respectively, Table 2).

4. Discussion

In the chain of survival, early recognition and intervention in cardiac arrest are of uppermost importance. In case of out-of-hospital cardiac arrest, essential bridging until the arrival of EMS most frequently has to be performed by laymen who thus potentially influence survival, prognosis and outcome of the patient [1,5,6,9]. Effective chest compressions are a key element of successful CPR. Recently, their importance has been further highlighted and changes in guidelines included a focus on chest compression with more as well as deeper compressions and initialization of CPR with chest compression instead of ventilation [6,8]. Even though evidence available is not sufficient to change current practice and to generally promote chest compression-only CPR, according to the ERC Guidelines for Resuscitation 2015 in endorsement of a recommendation of the International Liaison Committee on Resuscitation (ILCOR), all CPR providers should perform chest compressions for all victims in cardiac arrest, CPR providers trained and able to perform rescue breaths should combine chest compressions and rescue breaths [6].

In our analysis, general willingness of laymen to perform CPR was high, but more than one third of the participants expressed fears of contact. Analysis of chest compression parameters revealed that the success rates of laymen regarding compression depth and frequency were extremely low when conventional CPR was performed. To a lesser extent, the latter was also true for medical students and staff. Quality of CPR is essential to improve outcome [6]. Too slow compression results in an insufficient circulatory effect and in inadequate perfusion whilst too high compression rates decrease cardiac output because of impaired venous return aside from potentially impairing coronary perfusion. While both, too deep and too shallow compressions likewise impact arterial pressure and seem to be associated with poorer outcomes, wrong hand positioning or inaccurate compression depth and force can result in injuries such as fractures, organ lacerations or pneumothorax with associated mortality and morbidity [5,10–12]. When using the Cardio First Angel™ device, a remarkable 100% of correct hand positioning was achieved throughout all groups. Additionally, especially laymen showed a significantly improved and approximately doubled success rate of correct compression depth when using the device. Besides these direct effects on chest compression performance, the device might additionally aid to overcome fears. The vast majority of participants stated that they would use an assisting device and a substantial number had expressed fears of contact. Improvement in compression frequency when using the Cardio First Angel™ was significantly higher for probands with fears of contact in general and for probands with fear of physical contact/blood/body fluids. Besides the actual fear, translation of skills from training environments to a real life situation which is stressful, mentally demanding and potentially disorganized imposes additional obstacles [11,13]. Holmberg et al. reported that bystander CPR was attempted in only 36% of patients suffering out-of-hospital cardiac arrest and Wissenberg et al. reported a rate of 21.1% which

increased to 44.9% after national initiatives were taken to improve cardiac arrest management [5,9]. Potential indirect effects could include increasing the rate of performed bystander CPR via overcoming fears, raising the attention towards CPR as well as shortening the time interval from collapse to starting resuscitation and thus minimizing no-flow and ischemic time. Additional studies will be needed to undermine these hypotheses. The device seems to be self-explanatory even when used by laymen as we saw no differences in its beneficial effect achieved in laymen with versus without explanation.

Besides clear beneficial effects in laymen, we saw significantly more chest compressions performed with correct depth in medical students when using the Cardio First Angel™. Regarding compression frequency and correctness of hand positioning, medical students showed a high success rate even without the device which was most likely due to recent extensive CPR training. Since especially correctness of compression frequency by far outnumbered the rates of the other groups, this clearly underscores the importance of CPR training.

Wik et al. analyzed the quality of out-of-hospital real life CPR performed by ambulance personnel, as measured by adherence to CPR guidelines. They found that chest compressions were not delivered in a substantial proportion of time and that most compressions were too shallow. All involved personnel had undergone a refresher course in ALS prior to the study period [11]. Likewise, Abella et al. analyzed the quality of CPR during in-hospital cardiac arrest and found that, even though performed by well-trained hospital staff, the quality of multiple parameters of CPR was inconsistent and often did not meet guideline recommendations [13]. This is of particular interest since only a few studies examined CPR performance in real life situations and it demonstrates that even resuscitation as performed by professionals is far from ideal. The findings underline the importance of high-quality and high-frequency recertification of medical staff in BLS and ALS. In our analysis, medical staff likewise showed clear shortages in chest compression performance. Whilst correctness of hand positioning was 92.6% without and 100% with the CFA, no significant differences were observed for compression depth and frequency. Vahedian-Azimi et al. performed a randomized controlled clinical trial investigating standard manual CPR versus CPR using the Cardio First Angel™ in patients with cardiac arrest in mixed medical-surgical intensive care units (ICU) of academic teaching hospitals. Before the start of the study, all ICU nurses (who performed the chest compressions) received standardized CPR training in addition to formal training with the Cardio First Angel™ device. Even though, for example, absolute compression depth and frequency are not provided, adherence to CPR guidelines as well as CPR quality as determined by dedicated scores were significantly improved in the intervention group and return of spontaneous circulation (ROSC) was observed significantly more often. Furthermore, a decrease in rib fractures was reported [8]. A direct comparison of the results of Vahedian-Azimi et al. with those of our analysis is not feasible since first, the data were obtained in a training setting versus in real-life situations and second, they used a more comprehensive model for the analysis of CPR performance. However, it may be assumed that also medical professionals could benefit from assisting devices especially in real-life situations, either via direct or via indirect effects, and further analyses are clearly warranted.

A number of devices to assist in CPR and to ensure consistency and quality of chest compressions have been proposed [8]. In general, they comprise feedback and/or prompting functions and intend to improve CPR quality with the aim to increase ROSC and ultimately survival. Proposed forms of feedback include voice prompts, metronomes, visual dials, numerical displays, waveforms, verbal prompts and visual alarms, i.e. technology ranges from simple metronomes to more complex devices that monitor and provide real-time audiovisual feedback. They may or may not be associated with automated external defibrillators (AEDs) and even smartphone applications have been developed [6,8,14]. A number of devices that are positioned between the resuscitator's hand and the patient's chest, comparable to the Cardio First Angel™, have been tested in simulation settings. Several studies reported beneficial results for

various devices including the CPR-plus™ (Kelly Medical Products, Inc., Princeton, USA), CPREzy™ (Health Affairs, London, UK) and the Laerdal CPRmeter™ (Laerdal, Stavanger, Norway) [15–19]. Contrastingly, Zapletal et al. investigated the efficiency of chest compressions comparing three CPR feedback devices (Zoll PocketCPR® (Zoll Medical, Chelmsford, USA), Laerdal CPRmeter™, the iPhone app Zoll PocketCPR® (Zoll Medical, Chelmsford, USA)) and standard BLS in an open, prospective, randomized controlled trial in a simulated setting with a testing period of 8 minutes. Even though there were several differences between the feedback devices and standard BLS, none of the devices was able to achieve an improvement in compound parameters for chest compression quality compared to standard BLS [14].

Most of the devices depend on sufficient battery capacities. The Cardio First Angel™ provides a mechanically generated feedback of compression depth and release via springs. It does thus not depend on battery capacities or algorithms to determine compression depth. Furthermore, the auditory feedback provided as soon as sufficient compression and decompression have been achieved does not require focusing on potentially small displays or lights [8]. Another concern raised by Zapletal et al. is that usage of an adjunct device may delay starting CPR [14]. Whether this proves to be significant in a real-life setting and if so, whether this might be counterbalanced by an overall increased rate of attempted CPR due to secondary effects of the devices, remains to be demonstrated. Altogether, current guidelines do not recommend any assisting device since clear evidence consistently voting for their usage is lacking. Several studies report conflicting data, parts of the discrepancies may arise from using single key parameters such as compression depth, frequency and position versus more comprehensive models. It still has to be determined which approach will be more suitable for analysis of CPR and especially which will prove better correlation to performance in real-life situations and to relevant effects such as improving ROSC and survival. Additional factors limiting comparability include the test setting, the tested cohorts and differences in the tested devices themselves. Altogether, there seems to be a fundamental need for guidance and feedback during bystander CPR as otherwise there is no option for the resuscitator to evaluate whether chest compressions are satisfactory. Clear indicators that adjunct devices may have beneficial effects justify further structured analyses to eventually provide guidelines on their usage.

5. Limitations

Main shortages of our analysis include that it did not test for decompression and pauses or interruptions in chest compression. Furthermore, the analyzed period was rather short not representing the delay to be expected until EMS arrive. We did not analyze rescuer fatigue and differences in fatigue with and without the device. Additionally, due to the crossover design of the study, a potential individual learning effect of uncertain magnitude cannot be ruled out. Only one group received an explanation of the device which might have led to hypervigilance serving as a confounder in this group. Further considerations related to the device itself that have been raised include that it does not account for more complex aspects such as compressibility of the surface on which the patient is lying and changes in chest wall compliance and elasticity during CPR [8]. Additionally, this was a manikin-study under simulation conditions and results may not necessarily be extrapolated to real-life scenarios. Clearly, further studies are warranted.

6. Conclusion

Bystander CPR seems to be of utmost importance but human factors and human error will influence its quality in both laymen and healthcare professionals. Providing guidance and support via adjunct

devices has been proposed. With growing evidence that chest compressions are becoming an increasingly important part of CPR, the Cardio First Angel™ as a new and totally mechanical device has been developed to increase chest compression quality, efficiency and consistency. In our analysis, correctness of manual chest compression in laymen was significantly improved with regard to compression depth when using the device. Furthermore, with the device, no cases of incorrect hand positioning occurred. Additional and especially clinical studies are required to assess the relevance and potential benefit of assisting devices.

Conflict of interest

None of the authors has a conflict of interest. Cardio First Angel UG (Munich, Germany) donated the Cardio First Angel™ device and provided the CPR manikin as well as the software but was not involved in study planning, analysis of the results or in writing the manuscript.

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