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Chest compression depth after change in CPR guidelines—Improved but not sufficient☆

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ABSTRACT

Aims: Cardiopulmonary resuscitation is one of the most vital therapeutic options for patients with cardiac arrest. Sufficient chest compression depth turned out to be of utmost importance to increase the likelihood of a return of spontaneous circulation. Furthermore, the use of real-time feedback-systems for resuscitation is associated with improvement of compression quality. The European Resuscitation Council changed their recommendation about minimal compression depth from 2005 (40 mm) to 2010 (50 mm). The aim of the present study was to determine whether this recommendation of the new guidelines was implemented successfully in an emergency medical service using a real-time feedback-system and to what extend a guideline-based CPR training leads to a “change in behaviour” of rescuers, respectively.
Methods and results: The electronic resuscitation data of 294 patients were analyzed retrospectively within two observational periods regarding fulfilment of the corresponding chest compression guideline requirements: ERC 2005 (40 mm) 01.07.2009–30.06.2010 ($n = 145$) and ERC 2010 (50 mm) 01.07.2011–30.06.2012 ($n = 149$). The mean compression depth during the first period was 47.1 mm (SD 11.1) versus 49.6 mm (SD 12.0) within the second period ($p < 0.001$). With respect to the corresponding ERC Guidelines 2005 and 2010, the proportion of chest compressions reaching the minimal depth decreased (73.9% vs. 49.1%) ($p < 0.001$). There was no correlation between compression depth and patient age, sex or duration of resuscitation.
Conclusions: The present study was able to show a significant increase in chest compression depth after implementation of the new ERC guidelines. Even by using a real-time feedback system we failed to sustain chest compression quality at the new level as set by ERC Guidelines 2010. In consequence, the usefulness of a fixed chest compression depth should be content of further investigations.

1. Introduction

Sudden cardiac arrest is the most common cause of death worldwide.[1] Cardiopulmonary resuscitation (CPR) is one of the most vital therapeutic options for patients with cardiac arrest. Therefore, improvement of the algorithms both for basic life support and advanced life support has been content of discussion and research for years.[2–5]

Several changes have been made regarding the importance of interventions during the latest guidelines. Especially the importance of “high quality” chest compressions has been changed throughout the last years with a focus on minimizing the time without chest compression and release of compression depth.[6–9] According to an investigation of Wik et al. in 2002, only 28% of the performed chest compressions during cardiopulmonary resuscitation were within the requested depth[10] Stiell et al. described the resuscitation data of 1.029 patients. In this study, the portion of compliant chest compressions according to the European Resuscitation Council (ERC) Guidelines 2005 and 2010 were 47.2% and 8.4%, respectively.[11] While the ERC Guidelines 2005 advised a compression depth of at least 40 mm, the actual ERC Guidelines 2010 recommend a minimal compression depth of 50 mm instead.[12] Furthermore, the guidelines recommend the use of chest compression feedback-systems to monitor and improve chest compression

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quality.[13] The rationale for this focus on chest compression is the prioritization on a sufficient circulation and so increase the likelihood of a return of spontaneous circulation (ROSC).

The aim of the present study was to determine whether the new recommendations concerning chest compression were implemented successfully in an Emergency medical service serving a city of 300,000 inhabitants. Therefore, we analyzed the sufficiency of chest compressions during cardiopulmonary resuscitation with a real-time feedback-system adapted to the ERC Guidelines 2005 (feedback-system set to a minimum of 40 mm) vs. 2010 (feedback-system set to a minimum of 50 mm) in the city of Muenster between July 2009 and July 2012.

2. Methods

2.1. Ethic approval

Our study complies with the Declaration of Helsinki. This analysis was approved by the ethics committee of the regional medical board of registration (Ärztekammer Westfalen Lippe) and the University of Muenster (Westfälische Wilhelms-Universität Muenster) on 10th September 2012. The present study was compliant with German ethical law and no further permissions were required.

2.2. Observational periods

In this retrospective analysis we compared the resuscitation data of 294 patients with sudden cardiac arrest within two observational periods:

ERC 2005 (performed in accordance with ERC Guidelines 2005): 01.07.2009–30.06.2010 ($n = 145$).

ERC 2010 (performed in accordance with ERC Guidelines 2010): 01.07.2011–30.06.2012 ($n = 149$).

Inclusion criteria of the present study were the performance of chest compressions, the availability of the electronic resuscitation data and an entry in the German resuscitation registry (GRR©). No further exclusion criteria like age, sex or ethical origin were defined.

In 2007 all ambulances of the fire department Muenster were equipped with the real-time feedback-systems for resuscitation. Emergency physicians and ambulance personnel were trained prior to the observational periods in 90 min lectures according to the actual ERC guidelines followed by a practical training. Focus was on CPR quality and use of the real-time feedback-system. CPR training was repeated annually. Ambulance personnel as well as emergency physicians used an integrated real-time feedback-system in order to maintain surveillance regarding the compression quality, frequency and time without compression. The feedback system used in this study was a defibrillator with an accelerometer integrated into the defibrillation pads (Zoll E-Series and AED-pro both using CPR-D Padz, ZOLL Medical Corporation, Chelmsford, MA, USA). The accelerometer sensor is placed in the middle of the sternum at the compression point. Patients had to be positioned on a hard surface (floor or stretcher) to ensure correct measurements. This method has been described in previous studies.[9,10,14,15] The feedback system provides audial and visual prompts guiding chest compressions during CPR. Chest compression quality data is recorded. Feedback is provided by a visual bar graph, indicating chest compression depth. Additionally, verbal prompts are given and an acoustic metronome is beeping at 100/min. whenever compression frequency is below 100/min. Both devices are equipped with Real CPR Help® software (ZOLL Medical Corporation, Chelmsford, MA, USA). A software-update regarding the minimal compression depth was performed prior to the second study-period (ERC 2010).

2.3. Data acquisition

Loss of data occurred in 29 cases. 17 cases were performed with a non-local ambulance without feedback-system. Furthermore, technical defects of the feedback-system were registered in 19 cases (see Fig. 1). The corresponding cases were consequently eliminated from the analysis.

The resuscitation data were extracted from the defibrillator via USB and analyzed with the RescueNet Code Review© 4.10 Software (Zoll DATA Systems, Bloomfield, CO, USA). Inadvertend movements of the accelerometer were excluded by filtering all data: In case of artefacts (due to dislocation of electrodes, disconnection of cables and transport) the affected data were consequently removed from the analysis by using the RescueNet Code Review© 4.10 Software (Zoll DATA Systems, Bloomfield, CO, USA).

Sufficiency of chest compression was defined in accordance with the respective guidelines (compression depth at least 40 mm or 50 mm, respectively).

Primary endpoint of the present study was the proportion of chest compressions reaching the minimal depth according to the corresponding guidelines within the observational period.

2.4. Statistical approach

Statistical analysis was performed with SPSS 21.0© software (SPSS Inc., Chicago, IL, USA). If not explicitly specified, data are presented as mean (±SD). In order to test differences in baseline characteristics and resuscitation data between the groups, chi-squared tests and t-tests were considered as appropriate. Correlations were described with Pearson's correlation coefficient. Generalized estimating equations (GEE) including Wald statistics were used to control for the clustering of chest compressions from within events and to analyze a possible relationship between chest compression depth, gender and age.

3. Results

3.1. Demographic data

The mean patient age during the first period (ERC 2005) was 69.2 years versus 69.8 years within the second period (ERC 2010) without statistical significance. 199 of the 294 patients (67.7%) were male. This relation of gender was also observed within the two cohorts without significant differences (see Table 1).

3.2. Chest compressions

307,956 chest compressions in 145 cases were registered during the first period (ERC 2005) versus 320,870 recorded chest compressions during the second period (ERC 2010) with 149 cases. The mean compression depth of all recorded chest compressions was 48.3 mm (SD 11.7). During the first period (ERC 2005), the mean compression depth was 47.1 mm (SD 11.1) versus 49.6 mm (SD 12.0) within the second period (ERC 2010) (see Fig. 3 and Table 3). Analysing each resuscitation-event, the compression depth in mean is 47.0 mm in the first period and 50.3 mm in the second observational period ($p = 0.004$) (see Fig. 2 and Table 2). Transferring the data to the corresponding ERC recommendation of 2005 and 2010, respectively, 73.9% of the chest compressions during the first period (ERC 2005) were considered as "compliant" versus 49.1% of the chest compressions throughout the second period (ERC 2010). Further resuscitation data are listed in Tables 2 and 3.

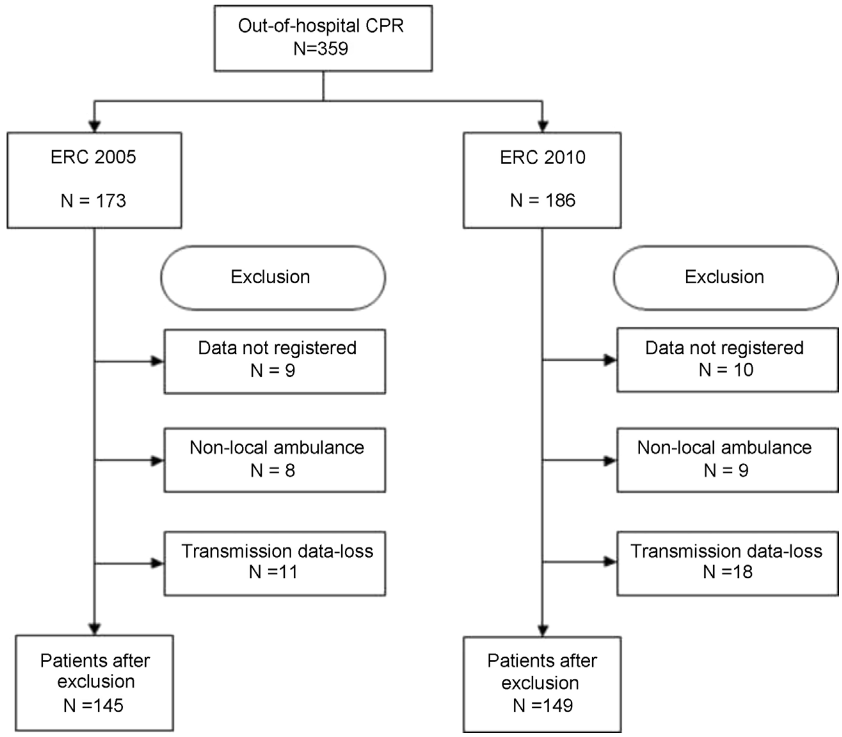

Fig. 1. Exclusion process. CPR: cardiopulmonary resuscitation, ERC: European resuscitation council

3.3. Correlations

No correlation between compression depth and duration of resuscitation (Pearson correlation coefficient $r_P = -0.062$) was found. Additionally a correlation between patient age and compression depth could not be observed within this trial (Pearson correlation coefficient $r_P = -0.09$). Furthermore, the mean compression depth and the increase in depth were more pronounced in

Table 1
Patient data.

	All patients	ERC 2005	ERC 2010	*p*-Value
Resuscitation attempts	294	145	149	
Age, mean [years]	69.5	69.2	69.8	0.76
(Range)	(17.7–100.6)	(24.5–97.8)	(17.7–100.6)	
Gender (%)				
Men	199 (67.7)	100 (69.0)	99 (66.4)	
Women	95 (32.3)	45 (31.0)	50 (33.6)	
ROSC to emergency department (%)				
ROSC	140 (47.6)	71 (49.0)	69 (46.3)	
No ROSC	154 (52.4)	74 (51.0)	80 (53.7)	
Initial rhythm (%)				
Shockable	87 (29.6)	47 (32.4)	40 (26.8)	
Non shockable	207 (70.4)	98 (67.6)	109 (73.2)	
Number of shocks (SD)	1.8 (3.1)	2.0 (3.4)	1.6 (2.8)	0.33
(Range)	(0–18)	(0–16)	(0–18)	
Interventions (%)				
Endotracheal intubation	222 (75.5)	129 (89.0)	93 (62.4)	
Shock	128 (43.5)	63 (43.4)	65 (43.6)	
Epinephrine	230 (78.2)	120 (82.8)	110 (73.8)	
Bystander witnessed? (%)	176 (60.0)	86 (59.3)	90 (60.4)	
Location (%)				
Home/residence	213 (72.4)	108 (74.5)	105 (70.5)	
In public	62 (21.1)	31 (21.4)	31 (20.8)	
Hospital	9 (3.1)	2 (1.4)	7 (4.7)	
Unknown	10 (3.4)	4 (2.8)	6 (4.0)	
Bystander CPR (%)	69 (23.5)	30 (20.7)	39 (26.2)	
Response time min (SD)	6.1 (5.1)	6.1 (2.8)	6.0 (5.5)	0.81
(Range)	(1–19)	(1–16)	(1–19)	

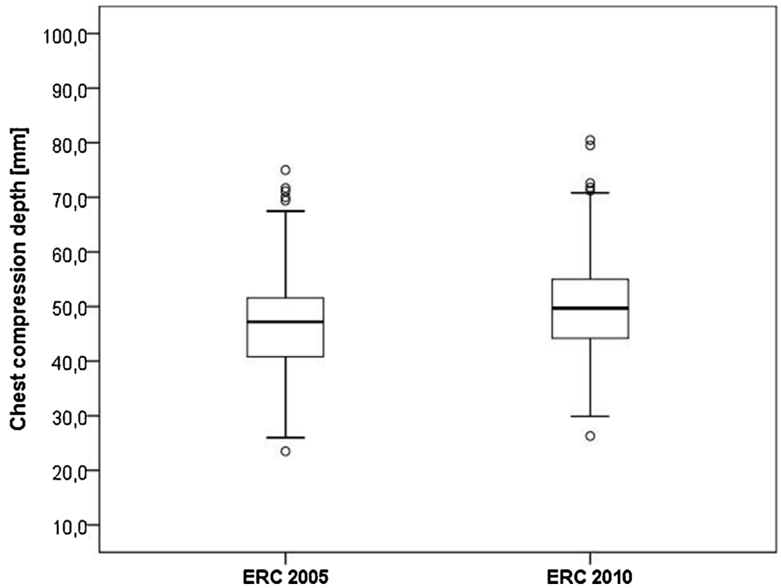

Fig. 2. Chest compression depth ERC 2005 vs. ERC 2010 Event-level (Boxplot).

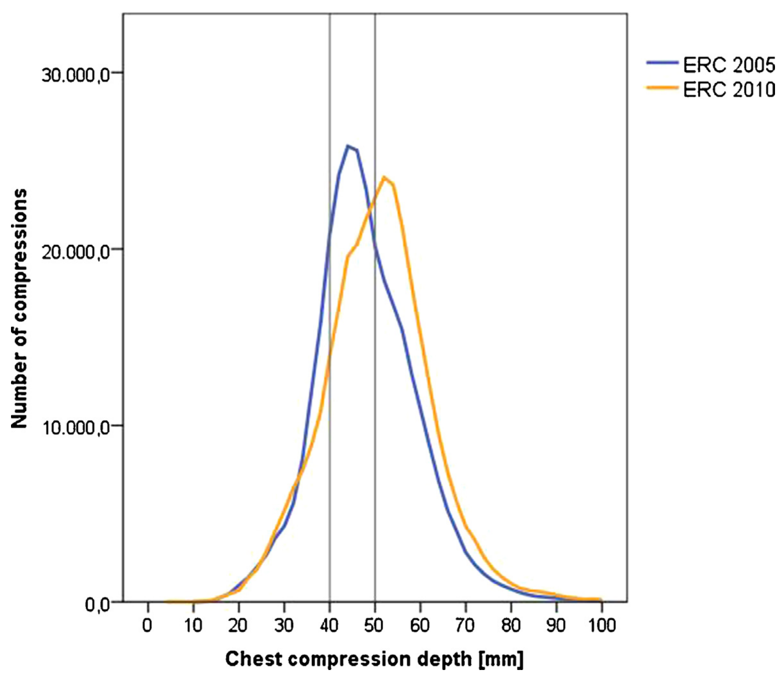

Fig. 3. Cumulated Chest compressions during the two study-periods (Graph). "Minimal guideline chest compression depth" symbolized with grey lines at 40 and 50 mm, respectively

Table 2
Chest compressions – event-level.

	All patients	ERC 2005	ERC 2010	*p*-Value
Resuscitation attempts	294	145	149	
Chest compression depth mean (SD) [mm]	48.7 (9.9)	47.0 (9.5)	50.3 (10.0)	0.004
Chest compression depth mean (SD) [mm] related to gender				
Men	49.3 (9.7)	47.1 (8.8)	51.5 (10.1)	0.001
Women	47.4 (10.2)	46.9 (11.1)	47.9 (9.5)	0.622
Resuscitation attempts reaching current minimal chest compression depth in mean (%)		108 (74.5)	82 (55.2)	<0.001
Chest compression rate mean (SD) [/min]	104.4 (8.9)	103.8 (6.1)	104.9 (11.1)	0.341
Fraction without chest compression % (SD)	10.4 (7.60)	10.7 (7.60)	10.1 (7.60)	0.441
Duration of Chest compression min (SD)	21.8 (17.3)	22.8 (15.0)	21.0 (19.4)	0.381

Table 3
Chest compressions – compression-level.

		ERC 2005	ERC 2010	*p*-Value
Number of all compressions	628.826	307.956	320.870	
Fraction of chest compressions reaching current minimal chest compression depth (%)		73.9	49.1	<0.001
Chest compression depth mean (SD) [mm]	48.3 (11.7)	47.1 (11.1)	49.6 (12.0)	<0.001

male patients as compared to the female patients (m: 47.1 mm vs. 51.5 mm (p = 0.001); f: 46.9 mm vs. 47.9 mm (p = 0.622)) (see Table 2).

Using multivariate generalized estimating equations (GEE) we could verify the differences between the two periods regarding chest compression depths (p = 0.0044). No significant influence on chest compression depth was found neither for gender (p = 0.2252) nor patient age (p = 0.3039).

4. Discussion

The present study was able to show a significant increase of chest compression depth in patients undergoing cardiopulmonary resuscitation in Muenster between July 2009 and July 2012 (47.0 mm vs. 50.3. mm, p = 0.004). However, with respect to the corresponding ERC Guidelines 2005 and 2010, the proportion of compliant chest compressions decreased from the first (ERC 2005) to the second period (ERC 2010) (73.9% vs. 49.1%, p < 0.001). At a first glance, it seems as if the quality of chest compressions during cardiopulmonary resuscitation in Muenster has been improved to insufficiency.

The status of "high quality" chest compression during cardiopulmonary resuscitation has been raised throughout the last years.[9,16] According to a consensus statement of the American Heart Association (AHA), there are five critical components of high-quality CPR: "minimize interruptions in chest compressions, provide compressions of adequate rate and depth, avoid leaning between compressions, and avoid excessive ventilation".[17] An investigation of Stiell et al. was able to show a clear association of survival outcome and increased compression depth.[11] However, the portion of compliant chest compressions with respect to the corresponding guidelines was low: while 47.2% of the recorded compressions met the criteria of the ERC Guidelines 2005, only 8.4% were considered "compliant" according to the Guidelines 2010, the mean compression depth within this trial was 37.3 mm.[11] Furthermore, the rate of ROSC was 25.7%, which is quite low as compared to 47.6% within the present trial (see Table 1). Edelson and colleagues described an association between shallow chest compressions and less successful defibrillation, which also underlines the importance of compliant compression depth.[16] The implementation of real-time feedback-systems during CPR turned out to improve preclinical resuscitation quality[18] and allowed to perform CPR more close to the aims of the ERC Guidelines 2005.[19] However, though the ERC 2005 requirements could be achieved with a feedback-system more easily, the definition of the "new" standards (ERC 2010) might be problematic regarding the accessibility (see also Stiell et al.).[11]

According to the demographic data, the investigated cohorts are homogenous regarding the distribution of age and gender.

4.1. *Staff training*

Prior to the study-periods the ambulance personnel was trained identically with respect to the corresponding ERC guideline on the Manikin Ambu Cardiac Care Trainer System W®. The same real-time feedback-system was used during training and patient care. Minimal training-goals for chest compression were set to 40 (ERC 2005) or 50 mm (ERC 2010). According to the manufacturer, the maximal compression depth of the manikin is about 75 mm with a thorax diameter of 190 mm. So from this point of view, it was possible to reach the required compression depth of 50 mm during the training sessions. Baubin et al. investigated the elastic properties of several CPR manikins and described a *linear* relationship between power and compression depth.[20] On the other hand, Tsitlik et al. found out that this interrelation of power and compression depth in human beings could be described as a second-degree *polynomial* function.[21] Due to this, more power is required with increasing compression depth in human beings. This might be a possible explanation why the compression depth in patients was improved between the first period (ERC 2005) and the second period (ERC 2010) without meeting the actual ERC requirements.

4.2. *Biomechanical parameters*

With increasing age of the patients the elasticity of the thorax decreases.[22] Due to this, the risk of rib fracture in elder patients undergoing CPR is higher as compared to younger patients.[22–24] This means in consequence, that the sternum of the elder patients undergoing CPR might not return to its starting position during compression release. The feedback-system recognizes a decrease in compression depth and thus alerts to improve compression. Interestingly, no correlation between age and compression depth could be found within the present investigation. The possible role of gender concerning the compression depth has already been discussed by Tomlinson et al. According to their observations regarding sex and compression depth during CPR, less power is needed within female patients to reach a compression depth of 38 mm as compared to male patients.[25] In addition to this, the thoracic diameter of male patients is usually greater as compared to female patients. Due to an investigation of Pickard et al., the mean sagittal thoracic diameter within a male patient collective was 252.8 mm versus 234.6 mm within a female collective.[26] Within the present study, the increase of compression depth in male patients was more pronounced then in female patients, especially during the second period (ERC 2010). This indicates that there was an attempt to implement the new ERC compression depth recommendation in Muenster during the periods. However, the improvement was more pronounced in male patients, maybe for anatomic reasons.

4.3. *Status of fixed goal parameters*

The rising portion of "incompliant" chest compressions during the second period (ERC 2010) in spite of these improvements should be a reason to think about the sense, status and accessibility of a fixed compression depth recommendation during CPR. On the one hand, the guidelines shall not be more complicated than necessary for reasons of comprehensibility. On the other hand, the application of a fixed parameter (compression depth) on an individual setting (thorax diameter, elasticity etc.) might not be the "sorcerers' stone". Since one size does not fit all, alternative concepts of "sufficiency control" regarding CPR should be content of further investigations. For instance, the monitoring of expiratory carbon dioxide levels during CPR might be an alternative indicator for the sufficiency of the chest compressions.[27] Realistic capnography during CPR indicates a blood flow within the lung which allows a kind of gas exchange. Since the aim of chest compressions is the maintenance of blood *flow*, the opportunity of measuring blood flow during CPR might be a worth consideration for the future. Further ideas might be the use of transcraniel Doppler ultrasound in order to measure cerebral blood flow during CPR[28] or the use of pulse-wave Doppler on the carotid artery.

4.4. Clinical impact

Whether a 2.5 mm improvement of compression depth has a clinical meaning is highly questionable. ROSC-rates were not affected by compression depth achieved in this trial. However, this study was able to show that the implementation of new guidelines in fact led to a change in rescuers behaviour concerning chest compression depth. Further studies are needed to determine the clinical impact of these findings.

5. Conclusion

The present study was able to show a significant increase in chest compression depth in patients undergoing CPR in Muenster between July 2009 and July 2012. With respect to the corresponding ERC guidelines, we failed to sustain chest compression quality at the new level as set by ERC guidelines 2010. In consequence, the usefulness of a fixed chest compression depth should be studied further with respect to the individuality of patient anatomy.

Limitations

There are some limitations regarding the present investigation that shall be mentioned: because of the lack of data regarding weight and height, we were unable to provide information regarding the anatomic conditions of the patients. Positioning of the patients on a hard surface was regulated by a Standard Operating Procedure but could not be controlled. Furthermore, the manufacturer of the feedback-system declares an accuracy of about 6.25 mm. However, because the same system was used in all 294 cases one can assume that the detected differences between the groups are reliable and valid.

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Conflict of interest statement

None author had conflict of interest.

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