Title page

Article type: Clinical Research Article

Manuscript title: Association of real-time feedback and cardio-pulmonary-resuscitation quality delivered by ambulance personnel for out-of-hospital cardiac arrest

Authors: Rasmus Meyer Lyngby[1,2], PhD; Tom Quinn[2], PhD; Roselil Maria Oelrich[1], Dimitra Nikoletou[2], PhD; Mads Christian Tofte Gregers[1,4], MD, PhD; Julie Samsoee Kjoelbye[1,4], MD; Annette Kjaer Ersbøll[1,5], PhD; Fredrik Folke[1,3,4], MD, PhD

Affiliations: [1]Copenhagen Emergency Medical Services, Copenhagen, Denmark. [2]Kingston University and St. Georges, University of London, London, United Kingdom. [3]Herlev Gentofte University Hospital, Copenhagen, Denmark. [4]Dept of Clinical Medicine, University of Copenhagen, Copenhagen, Denmark. [5]National Institute of Public Health, University of Southern Denmark, Copenhagen, Denmark.

Corresponding author: Rasmus Meyer Lyngby, Telegrafvej 5A, 2750 Ballerup, Denmark, e-mail: rasmus.meyer.lyngby@regionh.dk, Phone +45 38 69 80 00

Institution: Copenhagen Emergency Medical Services, Copenhagen, Denmark

Background

High-quality Cardio-Pulmonary-Resuscitation (CPR) is associated with improved survival from Out-of-Hospital Cardiac Arrest (OHCA) and includes chest compression depth, chest compression rate, and chest compression fraction within international guideline recommendations. Previous studies have demonstrated divergent results of real-time feedback on CPR performance and patient outcomes. This study investigated the association between Emergency Medical Service CPR quality and real-time CPR feedback for OHCA

Methods and Results

This study collected OHCA data within the Capital Region of Denmark and compared CPR quality delivered by ambulance personnel. Data were collected in two consecutive phases from October 2018 to February 2020.

Median chest compression depth in cm was 6.0 (no feedback) and 5.9 (real-time feedback) (p=0.852). Corresponding proportion of guideline-compliant chest compressions for depth was 16.6% and 28.7%, respectively (p=<0.001). Median chest compression rate per minute was 111 and 109 (p=<0.001), respectively. Corresponding guideline adherence proportion for compression rate was 65.4% compared to 80.4% (p=<0.001), respectively. Chest compression fraction was 78.9% compared to 81.9% (p=<0.001), respectively. The combination of guideline-compliant chest compression depth and chest compression rate simultaneously was 8.5% (no feedback) versus 18.8% (feedback) (p=<0.001).

Improvements were not significant for return of spontaneous circulation (ROSC) (Odds ratio (OR) [95 % CI] = 1.08 [0.84, 1.39]), sustained ROSC (OR 1.00 [0.77, 1.31]), or survival to hospital discharge (OR 0.91 [0.64, 1.30]).

Conclusions

Real-time feedback was associated with improved guideline compliance for chest compression depth, rate, and fraction but not ROSC, sustained ROSC or survival to hospital discharge.

Registration

This study was conducted as a prospective cohort study and registered on clinicaltrial.gov (NCT04152252).

Keywords

OHCA, CPR, EMS, CPR quality, Real-time feedback

Clinical Perspective

What is new?

Despite median chest compression depth in cm not changing significantly between control and intervention groups in this study, the proportion of compressions within guideline recommendations almost doubled when paramedics were exposed to real-time feedback. Even though median chest compression depth in cm and median chest compression rate in compressions per minute were within guidelines in both groups, the proportion of compressions delivered according to guidelines improved significantly with real-time feedback. When combining guideline adherent depth and rate simultaneously for every compression delivered, CPR quality was generally low but more than doubled with real-time feedback.

What are the clinical implications?

During resuscitation the challenge in achieving guideline compliance must not be underestimated. Even with real-time feedback combining correct depth and rate in one compression is difficult. During chest compressions the compressor should not be assigned other tasks or focus on other tasks than performing compressions. When measuring CPR quality resuscitation officers and researchers should use combined parameters and measure guideline in proportion compliance and not the current mean/median measurements.

Abbreviations

AHA: American Heart Association

CCD: Chest Compression Depth

CCDiT: Chest Compression Depth in Target

CCF: Chest Compression Fraction

CCR: Chest Compression Rate

CCRiT: Chest Compression Rate in Target

CCiT: Combined Compressions in Target

CPR: Cardio-Pulmonary-Resuscitation

EMS: Emergency Medical Services

IQR: Interquartile Range (IQR)

OHCA: Out-of-Hospital Cardiac Arrest

ROSC: Return of Spontaneous Circulation

sd: Standard Deviations

sROSC: Sustained Return of Spontaneous Circulation

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

Introduction

Out-of-Hospital Cardiac Arrest (OHCA) is a major health problem in Europe, with approximately 275,000 cases treated by Emergency Medical Services (EMS) each year [1]. Overall survival is approximately 8-10%, but significant variation exists across countries [2,3]. Survival depends on optimal performance in the chain of survival with guideline adherent chest compressions being a key performance component in cardio-pulmonary-resuscitation (CPR) [4]. Current resuscitation guidelines from the European Resuscitation Council and the American Heart Association (AHA) recommend a chest compression depth (CCD) of 5 – 6 cm, a chest compression rate (CCR) of 100 – 120 compression per minute, a chest compression fraction (CCF) of at least 60% (AHA guidelines states 80%), a full release of the force exerted to the chest (recoil), ventilations with a duration of 1 second and a tidal volume of 500 – 600 ml per breath [4,5]. Real-time CPR feedback is available in several automated external defibrillators and professional EMS monitors. However, previous studies have reported divergent relationships between real-time feedback and CPR quality and patient outcome when EMS attend OHCA [6-8].

Out-of-hospital cardiac arrest occurs approximately 5,400 times each year in Denmark, with a quadrupling in survival from 4% to 16% since 2001 [9]. Improvement initiatives have been driven by implementing the 10-step OHCA survival strategy advocated by the Global Resuscitation Alliance and Resuscitation Academy [10]. Initiatives implemented include a continuously updated national OHCA register, telephone-assisted CPR, artificial intelligence to improve OHCA recognition, and dispatch of volunteer responders in suspected OHCA [9,11]. Furthermore, the 10-steps recommend high-performance CPR and the continuous measurement of professional resuscitation.

This study investigated whether real-time feedback for chest compressions was associated with improved EMS CPR quality (chest compression depth, rate and fraction) and patient outcomes (return of spontaneous circulation (ROSC), sustained ROSC (sROSC) and 30-day survival in an EMS system which has already improved OHCA survival.

Methods

Study design

This study was conducted as a prospective cohort study and registered on clinicaltrial.gov (NCT04152252). The study consists of two consecutive phases. Phase one (no feedback) was an 8-month phase from 1 October 2018 to 25 May 2019. Phase two (real-time feedback) was a 9-month phase from 26 May to 19 February 2020. This study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement [12].

Because of the sensitive nature of the data collected for this study, requests to access the dataset from qualified researchers trained in human subject confidentiality protocols may be sent to the corresponding author.

Ethics and approvals

We applied for ethical approval from The Danish National Committee on Health Research Ethics (H-18016462). The committee waived formal approval. Permission to collect data was obtained from the Danish Data Protection Agency (P-2021-670). Permission to store data was obtained from the Centre for Regional Development (R-2005114). According to Danish legislation, the study was regarded and conducted as quality assurance, which does not require patient consent.

Setting

Demographics

The study was conducted in the Capital Region of Denmark. The region covers 2,561 km^2 and is a mix of urban and rural areas and includes 1.82 million inhabitants with a population density of 709.7 inhabitants/km^2 [13]. The region has nine hospitals with emergency departments, with two being designated OHCA receiving facilities.

Emergency medical services and OHCA in study setting

Copenhagen EMS is a public organisation responsible for providing EMS to the population in the region. Copenhagen EMS operates the 1-1-2 medical triage of health-related calls and five physician-staffed mobile critical care units. Two independent companies provide Ambulances: Falck

and the Greater Copenhagen Fire Department [14]. Copenhagen EMS handles more than 120,000 1-1-2 emergency calls annually. Of these, 2.7% were categorised as unresponsive adults / suspected cardiac arrests [15]. Copenhagen EMS use artificial intelligence to aid the recognition of OHCA, dispatch volunteer responders by app, and provide telephone or video-assisted CPR to the caller [11,16,17]. The standard clinical response to OHCA is dispatch of the nearest ambulance and mobile critical care unit.

Participants and selection

We included adults ≥18 years old in OHCA who received CPR from EMS providers with a ZOLL® X-Series® defibrillator (ZOLL® Medical Corporation, Chelmsford, MA) attached to the patient. Patients and cases were excluded based on; 1: age <18 years, 2: if no EMS physician was involved, 3: if no CPR quality data remained after editing the case, 4: unidentifiable CPR quality pattern or 5: corrupted data.

Data collection and management

EMS initiates resuscitation on unconscious patients with no or abnormal breathing and where no do not resuscitate document is presented. Resuscitation attempts are continued until an emergency physician, present or by phone, finds the resuscitation attempt to be futile. This approach did not change during study phases.

Data on CPR quality was recorded using a ZOLL® X-Series® Defibrillator, which records chest compression data when paramedics attach an accelerometer-based sensor to the patient's chest. The sensor is a pressure pad situated between the provider's hands and the patient's chest. The sensor recorded thoracic movement and presented data as real-time feedback on the defibrillator screen in a CPR feedback dashboard (Figure S1). Paramedics manually transferred data to the CaseReview (ZOLL® Medical Corporation, Chelmsford, MA), a software allowing for review, editing, and exporting of cardiac arrest data.

CPR quality data was reviewed case-by-case and, if indicated, edited by one researcher (RMO) according to a pre-defined set of criteria and a procedure developed by the researchers (File S2,

Figure S3). Selected cases were reviewed by another researcher (RML) for verification or to make a final decision for complex patterns.

Cardio-pulmonary-resuscitation quality data from CaseReview was merged with regional verified OHCA data on patient characteristics and outcomes and analysed using STATA version 17 (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC).

Prior to the initiation of our study, paramedics were equipped with LifePack 15 defibrillators only delivering metronome audio guidance.

Exposure

During the no-feedback phase, paramedics attached the sensor to the patient's chest, but the CPR feedback dashboard (Figure S1) on the defibrillator was disengaged and not visible to paramedics.

In the real-time feedback phase, real-time feedback was displayed on the defibrillator screen, presenting compression depth as a numerical value with colour. Green indicated guideline compliance, and yellow indicated non-compliant compression depth. The compression rate was presented the same way. Furthermore, a metronome provided audible rate guidance. A bar indicated the release of force exerted to the chest. Before the real-time feedback phase, paramedics attended a 45-minute introduction to the feedback dashboard, including a 10-minute simulated OHCA scenario.

Outcomes

The following variables were collected from CaseReview: Chest Compression Depth in Target (CCDiT) (proportion of all compressions delivered within the recommended 5-6 centimetres depth), CCD (mean in centimetres), CCR (frequency mean), Chest Compression Rate in Target (CCRiT) (proportion of all compressions delivered within the recommended 100-120 compressions per minute), CCF (proportion of the total resuscitation time with chest compressions being performed), Combined Compressions in Target (CCiT) (proportion of guideline adherent compression depth in cm and rate in compressions per minute delivered simultaneously), and patient social security number.

The primary outcome was CCDiT. Secondary outcomes were CCD, CCRiT, CCR, CCF, CCiT, ROSC at any time during resuscitation, sROSC (ROSC at hospital handover) and 30-day survival. All CPR quality measurements were calculated from the first registered compression to the last registered compression.

Other variables

From the regional cardiac arrest database, the following variables were collected: sex, age, location of OHCA, OHCA witnessed by bystander, bystander defibrillation, EMS defibrillation, EMS response time, OHCA witnessed by EMS, first observed rhythm by EMS, bystander CPR, ROSC, sROSC, 30-day survival and patient social security number.

Sample size

With an estimated 115 OHCA cases each month in Copenhagen, 6-month data collection phases were planned to allow for the potential inclusion of 690 OHCA cases. Potential causes for data loss were incomplete data, unidentifiable patients, and technical issues. Data loss was estimated to be 5%, which allowed for 655 OHCA cases in each phase. The sample size was calculated based on the primary outcome. To detect a 15% improvement in chest compression depth with a 5% significance level and a power of 85% required a total of 1,162 patients, with 581 in each group.

In consultation with clinical experts within cardiology and medical education and simulation, a consensus was reached that an improvement should be at least 15 % to be clinically significant. A systematic review by Lyngby et al. [9] supported this, as the mean improvement in performance for guideline-adherent compression depth, rate, and fraction were 9.6 %, 9.9 %, and 9.8 % when real-time feedback intervention was used. The 9.6 %–9.9 % improvement was insufficient to detect changes in patient outcomes in the included studies. This suggested a CPR quality improvement of at least 10 % and possibly higher to translate into changes in patient outcomes.

Analysis population

The intention-to-treat population was defined as those who fulfilled the inclusion criteria. The as-observed population was defined as those for whom CPR quality and regional OHCA data had been recorded. No imputation was carried out. The as-observed population was the main analysis population.

Statistical analysis

Baseline characteristics are presented as numbers with corresponding percentages for binary and ordinal variables. Continuous variables are presented as means with corresponding standard deviations (sd) or median with interquartile range (IQR).

Shapiro-Wilk's test was used to evaluate a normal distribution of the five outcome variables.

The association between CCDiT and real-time feedback was tested using Wilcoxon Rank Sum Test.

The association between the continuous secondary outcomes (CCD CCR, CCRiT, CCiT and CCF) and real-time feedback was also tested using Wilcoxon Rank Sum Test. Logistic regression analyses were used to test the association between the binary outcome (ROSC, sROSC and 30-day survival) and real-time feedback. We did not adjust for any confounders as the study phases were controlled by date and hence not affected by potential confounders and thereby not eligible for adjustment. However, a semi and fully adjusted analysis did not change our results. The adjusted analysis can be found in supplementary (Table S4).

Results

Participants

A total of 1,697 patients were eligible for enrolment. CPR quality data were available for 1,065 (62,8%) patients. Pairing CPR quality data with the regional cardiac arrest database resulted in a total of 951 cases. After applying the exclusion criteria, 38 cases were excluded leaving 913 cases included (Figure 1).

Of the 913 patients included, 467 (51.2%) were in the no-feedback phase, and 446 (48.9%) were in the real-time feedback phase. The median (IQR) age was 74.0 (63.0-82.0) years with 64.5% (n=589)

being male. The OHCA primarily occurred in private homes (78.9%, n=720), with 48.9% (n=446) witnessed by relatives or bystanders. Bystander CPR was initiated in 68.1% (n=621) of the cases, with bystander defibrillation in 10.1% (n=92) of all cases. Paramedics witnessed the arrest in 9.8% (n=89) of the cases and initiated defibrillation in 27.4% (n=250) of all arrests. Mean (sd) EMS response time was 7.4 (5.4) minutes (Table 1) (Table S5)

Primary outcome

The real-time feedback group had a statistically significant higher proportion of correct chest compression depth (28.7%) compared with the no-feedback group (16.6%) (p<0.001). (Figure 2A) (Table 2).

Secondary CPR performance outcomes

We found a non-significant difference between the no-feedback and the real-time feedback group for CCD (p=0.85) (Figure 2B) (Table 2). The results for CCRiT (p=<0.001) (Figure 2C), CCR (p=<0.001) (Figure 2D), CCF (p=<0.001) (Figure 2E), CCiT (p=<0.001) (Figure 2F) were all significant (Table 2).

Secondary patient-centred outcome

We found no significant differences in the real-time feedback group compared to the no feedback group for: ROSC 31.8% (n=142) vs 33.2% (n=155), p=0.66, sROSC 23.9% (n=106) vs 27.0% (n=126), p=0.27, and 30-day survival 11.5% (n=51) vs 13.7% (n=64) p=0.30, respectively. Odds ratio are presented in Table 3.

Discussion

This study investigated the effect on CPR quality and patient outcome using real-time feedback for EMS attended OHCA. The main study findings were: (1) Despite median chest compression depth in cm (CCD) did not change significantly between the groups, the proportion of compressions within guideline recommendations (CCDiT) almost doubled when paramedics were exposed to real-time

feedback. (2) Even though median chest compression depth in cm (CCD) and median chest compression rate in compressions per minute (CCR) were within guidelines in both groups, the proportion of compressions delivered according to guidelines improved significantly (CCDiT and CCRiT) with real-time feedback. (3) When combining guideline adherent depth and rate simultaneously for every compression delivered (CCiT), CPR quality was generally low but more than doubled with real-time feedback. Nevertheless, the improvement in CPR quality found with real-time feedback did not translate into improved ROSC or 30-day survival; however, our study was not powered for patient outcomes.

Chest compressions depth and rate

Interestingly, our study demonstrated that when looking at the median CCD and CCR for the entire resuscitation attempt, these values were within guideline recommendations in both study groups. However, when CCD and CCR were investigated individually for every single compression delivered, only one out of six compressions for depth (CCDiT) and two out of three compressions for rate (CCRiT) were high quality without real-time feedback. In comparison, the guideline adherence for CCDiT almost doubled, and CCRiT improved by 15% in the real-time feedback period.

As CPR is associated with a reduction of 60-90% of the normal cardio-cerebral blood flow, OHCA patients require each compression throughout the resuscitation to be of high quality to ensure stable haemodynamics [18]. Combining CCDiT and CCRiT into one combined CPR compression quality score (CCiT) revealed that only one in eleven compressions were of high quality. Intervening with real-time feedback improved guideline adherence significantly to one in five compressions for CCiT. Our finding suggests that real-time feedback can improve CPR quality for depth and rate, both as individual variables and in combination, despite performance already appearing to meet guideline recommendations for high quality when measured as mean cm and compressions per minute across the entire resuscitation attempt. Current guidelines recommend compliant depth and rate as individual parameters for high quality but do not emphasise the importance of them being delivered simultaneously in each compression, which our study showed was rarely the case.

The CCDiT and CCRiT improvement and coherent lack of improvement in CCD and CCR could be explained by the approach to OHCA management. European guidelines dictate a change of

compressor every 2 minutes to avoid rescuer exhaustion [4]. The change of compressor allows providers to compensate for a team member's non-compliant performance, leading to a better final overall performance. This tendency was seen in some cases where one provider performed below guideline recommendations while another team member performed above guideline recommendations. This translated to an average CCD/CCR within guideline recommendations, although CCDiT/CCRiT remained low. In contrast, CCD/CCR could be outside guideline recommendations, while CCDiT/CCRiT were high.

Our findings demonstrated an almost identical CCD (-0.1 cm) when providers were exposed to real-time feedback. This differs from previous studies, where pre-hospital intervention with real-time feedback (defibrillator displayed) was reported to improve chest compression depth [19-22]. Hostler et al. was the only study reporting findings as significant [22]. However, to detect an improvement in any measured variable, the starting point is required to allow for an improvement. As paramedics in our study already performed guideline adherent CCD without real-time feedback, this variable did not allow for any improvement. The same tendency was seen for CCR. In contrast, other OHCA studies reported real-time feedback to improve CCR performance [19-22], with both Hostler et al. and Lakomen et al. reporting findings as significant [20-22].

As previously mentioned, when combining guideline adherent chest compression depth and chest compression rate delivered simultaneously in one compression (CCiT), we found that only one in eleven compressions in the no-feedback group were within guideline recommendation for both rate and depth delivered in the same compression. This improved to one in five for the real-time feedback group. This suggests that CPR quality measured in cm and compressions per minute and as individual variables may be an incomplete measurement for CPR quality. Furthermore, this finding may contribute to understanding the lack of translation of CPR quality improvement into improved patient outcomes in our and previous studies.

Chest compression fraction

Our study found a minor but still significant improvement in CCF following real-time feedback. This finding is supported by Sainio and colleagues [23] but is in contrast to several other studies [19-22,24], which reported non-significant changes favouring both feedback and no feedback. These non-

conclusive findings correspond with what could be expected by feedback in real-time. As real-time feedback prompts a change in performance during the resuscitation, and CCF is calculated retrospectively, it cannot reasonably be expected to influence providers' performance during the resuscitation attempt. Furthermore, CCF is affected by natural breaks and CCR. If CCR increases, so do the number of ventilation breaks according to the guideline-recommended 30:2 compression/ventilation ratio. The CCR delivered and potentially guided by real-time feedback, therefore affects CCF. In our study, the CPR feedback dashboard displayed a timer activated after a few seconds without chest compressions which counted the lapsed time without compressions. This feature could explain why we found CCF to improve, as the timer could have directed the providers' attention towards minimising periods without chest compressions.

Patient-centred outcomes

For the patient-centred outcomes, we found no significant changes. Similar findings were reported by Bobrow et al. and Hostler et al. [19,22]. Out-of-Hospital cardiac arrest is a multi-factor event where the outcome depends on several variables. This could explain our finding as the improvements achieved by intervening with real-time feedback may not be sufficient to influence clinical outcome despite their statistical significance. Furthermore, performing only one in five compressions according to guidelines may not be sufficient to affect outcomes. Finally, our study was not powered to detect ROSC or survival benefits.

Technology

The high quality CPR recommendations stated by the ERC are based on an average size adult making CPR a one-size fits all approach. Real-time feedback holds limitations and circumstances may arise where providers should deviate from the feedback received, for example in obese or underweight patients, or patients on soft surfaces. In such circumstances real-time feedback may inhibit the provider in delivering efficient compressions by providing feedback that either advise to compress deeper (in underweight patients) or inform those compressions are too deep (in obese patients or on soft surface). In such incidents compressions would be registered as non-guideline compliant while they in fact were effective as they were conducted according to patient size.

However, current guidelines do not recommend individualised CPR and still recommend an approach based on an average size adult.

Comparing the technology in our study to other technologies was outside the scope of this study but may be a factor in validating the results of our study. In a systematic review by Wang et al. [25] the authors found that outcomes relied on the type of defibrillator used which may indicate that either technology or presentation of real-time feedback may be an important factor in real-time feedback studies. An in-depth description of the various feedback technologies is described elsewhere [26].

Limitations

Several limitations should be considered when interpreting our results. First, we cannot rule out that our results originate from providers changing practice merely due to knowledge of the observation, also known as the Hawthorne effect; however, if this were the case, it would affect both the no-feedback and the feedback phase of the study [27].

Unfortunately, it was impossible to do the study as a RCT as the set-up of the defibrillator did not allow for rapid change of feedback function (on/off), nor was it possible for all ambulances to bring two defibrillators, one with real-time feedback and one without. The turnover between services and stations was estimated to be around 25% to 30% which would have caused a substantial risk of a carryover effect between intervention and control groups; hence a stepped wedge randomized cluster trial was abandoned.

Our study was conducted using a before/after study design. Previous studies have found that well designed cohort studies do not introduce a higher risk of bias compared to poor RCT designs which argued for a cohort design despite its limitations.

Our study is also limited by the technology used. We cannot determine the surface on which compressions were delivered. Therefore, if providers have adapted their compression depth to compensate for a soft compressible surface under the patient (e.g., a bed), their compressions would be registered as too deep by the sensor as it would and thereby, despite being clinically correct, be registered as outside guidelines recommendations. This phenomenon is referred to as

the mattress effect [28,29]. Furthermore, If paramedics were adapting compression depth to patient size with deeper compressions to compensate (individualised CPR) would be registered as non-compliant compressions. Data were collected using the manufactures software. Our data extraction and analysis were limited by the functionality of the software and accessibility to compression-by-compression data.

The dynamics of an OHCA includes an initial chaos-phase where it can be suspected that real-time feedback may provide better support than later in the arrest. However, we did not have access to data on the duration of the arrest. Therefore, we could not perform a time specific analysis of the different stages of the arrests or compare the duration and study phases to assess the strength of the association in the different stages of an arrest. Furthermore, we cannot rule out that the use of metronome guidance prior to our study caused an undetectable carryover effect.

Finally, our estimates were too optimistic in calculating data loss, and we did not reach the required sample size.

Conclusion

Based on 916 patients, real-time feedback was associated with improved chest compression depth, chest compression rate (individually and combined), and chest compression fraction guideline compliance. Overall quality for combined depth and rate was low but doubled with real-time feedback. Furthermore, our study indicates that current measurements of CPR quality should not be limited to average cm and compressions per minute for chest compression depth and chest compression rate but expanded to contain proportion within guideline recommendations both as individual variables and in combination.

Funding

TrygFonden, Denmark (grant number: 125963)

CaseReview software was provided free of charge by ZOLL® Medical Corporation for the duration of the study.

Acknowledgements

The authors wish to thank Lyra Clark and Annemarie Silver from ZOLL® Medical Corporation for providing technical support throughout the study.

Conflict of Interest Disclosures

None of the authors have any conflicts of interests to declare

List of the supplemental material

Figure S1: Feedback dashboard, File S2: Reasons for edit in CaseReview, Figure S3: Reviewing procedure and editing of data, Table S4: Significance level with adjustments, Table S5: Baseline characteristics (with statistical comparison).

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Title, legends, and abbreviations - Figures

Figure 1

Study flowchart

Abbreviations: CPR: cardio-pulmonary-resuscitation, CPRQ: cardio-pulmonary-resuscitation quality, EMS: emergency medical service, RCAR: regional cardiac arrest database

Figure 2

Chest compression quality

Figure 2A: Boxplots of the proportion of chest compression depth in target, figure 2B: Boxplots of chest compression depth in cm, figure 2C: Boxplots of the proportion of chest compression rate in target, figure 2D: Boxplots of chest compression rate in compressions per minute, figure 2E: Boxplots of chest compression fraction (flowtime), figure 2F: Boxplots of combined chest compression depth and rate proportion in target

Abbreviations: CCF: chest compression fraction, cm: centimetres, cpm: compressions per minute

Tables

Table 1

Baseline characteristics

Out-of-hospital cardiac arrest characteristics				
Variable / Phase	No feedback	Real-time feedback	Total	Missing values, n (%)
N, (%)	467 (51.2)	446 (48.9)	913 (100)	-
Age years, median (IQR)	74.0 (62.0-83.0)	74.5 (63.0-82.0)	74.0 (63.0-82.0)	0
Sex – male, n (%)	305 (65.3)	282 (63.9)	589 (64.5)	0
Location – private*, n (%)	378 (80.9)	342 (76.9)	720 (78.9)	0
First EMS recorded rhythm – shockable, n (%)	81 (17.8)	77 (17.6)	158 (17.7)	22 (2.4)
Witnessed by bystander, n (%)	218 (46.7)	228 (51.1)	446 (48.9)	0
Bystander CPR, n (%)	332 (71.1)	289 (64.9)	621 (68.1)	1 (< 1)
Bystander defibrillation, n (%)	49 (10.5)	43 (9.6)	92 (10.1)	0
Witnessed by EMS, n (%)	43 (9.2)	46 (10.3)	89 (9.8)	0
EMS defibrillation, n (%)	129 (27.6)	121 (27.1)	250 (27.4)	0

EMS response time, minutes (sd)	7.4 (5.9)	7.3 (4.8)	7.4 (5.4)	28 (3.1)	

[*] *Location was classified as either private or public*

Baseline characteristics of patients with out-of-hospital cardiac arrest included in the study

CPR: cardio-pulmonary-resuscitation, EMS: emergency medical services, sd: standard deviation.

Table 2

Outcome descriptives and significance

Phase	No feedback		Real-time feedback		Significance
Variable	*n*	*Descriptives*	*n*	*Descriptives*	*Probability*
CCD (cm), median (IQR)	467	6.0 (4.9 – 6.8)	446	5.9 (5.2 – 6.6)	= 0.852
CCDiT (%), median (IQR)	467	16.6 (3.3 – 35.2)	446	28.7 (8.8 – 48.9)	< 0.001
CCR (compressions per minute), median (IQR)	467	111.3 (105.6 – 117.6)	446	108.8 (105.9 – 112.8)	< 0.001
CCRiT (%), median (IQR)	467	65.4 (44.3 – 78.8)	446	80.4 (68.6 – 88.1)	< 0.001
CCF (%), median (IQR)	467	78.9 (72.6 – 84.0)	446	81.9 (77.3 – 86.3)	< 0.001
CCiT (%), median (IQR)	467	8.5 (0.9 – 21.2)	446	18.8 (5.3 – 37.9)	< 0.001

CCD: chest compression depth, CCDiT: chest compression depth in target, CCF: chest compression fraction, CCiT: compressions in target, cm: centimetre, CCR: chest compression rate, CCRiT: chest compression rate in target, IQR: interquartile range.

Table 3

Odds Ratio and proportion for patient-centred outcomes

Patient-centred outcome	Phase	n	Events, n (%)	Odds Ratio [95%CI]
ROSC	No feedback	467	155 (33.2)	1 (ref)
	Real-time feedback	446	142 (31.8)	0.94 [0.71 – 1.24]
sROSC	No feedback	467	126 (27.0)	1 (ref)
	Real-time feedback	445	106 (23.9)	0.85 [0.63 – 1.14]
30-day survival	No feedback	467	64 (13.7)	1 (ref)
	Real-time feedback	445	51 (11.5)	0.81 [0.55 – 1.20]

CI: confidence interval, ROSC: return of spontaneous circulation, sROSC sustained return of spontaneous circulation,

CRediT author statement

Rasmus Meyer Lyngby: Funding acquisition, Project administration, Conceptualisation, Investigation, Methodology, Formal analysis, Data Curation, Writing - Original Draft, Review and Editing.

Tom Quinn: Conceptualisation, Methodology, Supervision, Writing - Review & Editing

Julie Samsoee Kjoelbye: Writing - Review & Editing

Mads Tofte Gregers: Writing - Review & Editing

Annette Kjaer Ersbøll: Methodology, Formal analysis, Writing - Review & Editing

Roselil Maria Oelrich: Data Curation, Validation, Review & Editing

Dimitra Nikoletou: Methodology, Supervision, Writing - Review & Editing

Fredrik Folke: Conceptualisation, Funding acquisition, Project administration, Supervision, Formal analysis, Methodology, Writing - Review & Editing