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Comparison of Methods for the Determination of Cardiopulmonary Resuscitation Chest Compression Fraction

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Abstract

Objective—While cardiopulmonary resuscitation (CPR) chest compression fraction (CCF) is associated with out-of-hospital cardiac arrest (OHCA) outcomes, there is no standard method for the determination of CCF. We compared nine methods for calculating CCF.

Methods—We studied consecutive adult OHCA patients treated by Alabama Emergency Medical Services (EMS) agencies of the Resuscitation Outcomes Consortium (ROC) during Jan. 1, 2010 - Oct. 28, 2010. Paramedics used portable cardiac monitors with real-time chest compression detection technology (LifePak 12, Physio-Control, Redmond, Washington). We performed both automated CCF calculation for the entire care episode as well as manual review of CPR data in 1-minute epochs, defining CCF as the proportion of each treatment interval with active chest compressions. We compared the CCF values resulting from 9 calculation methods: 1) mean CCF for the entire patient care episode (automated calculation by manufacturer software), 2) mean CCF for first 3 minutes of patient care, 3) mean CCF for first 5 minutes, 4) mean CCF for first 10 minutes, 5) mean CCF for the entire episode except first 5 minutes, 6) mean CCF for last 5 minutes, 7) mean CCF from start to first shock, 8) mean CCF for the first half of resuscitation, 9) mean CCF for the second half of resuscitation. We compared CCF for Methods 2-9 with Method 1 using paired t-tests with a Bonferroni-adjusted p-value of 0.006 (99.5% confidence intervals).

Results—Among 102 adult OHCA, patient demographics were: mean age 60.3 years (SD 20.8 years), African American 56.9%, male 63.7%, and shockable ECG rhythm 23.5%. Mean CPR duration was 728 seconds (95% CI: 647-809 seconds). Mean CCF for the 9 CCF calculation methods were: 1) 0.587; 2) 0.526; 3) 0.541; 4) 0.566; 5) 0.562; 6) 0.597; 7) 0.530; 8) 0.550; 9) 0.590%. Compared with Method 1, Method 7 CCF (start to first shock) was slightly lower (−0.057; 99.5% CI: −0.100 – (−0.014)). There were no other statistically significant CCF differences (range: −0.054-0.013). Correlation between CCF 2-9 and CCF varied ($\rho=0.48-0.85$).

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Conclusion—CCF varies minimally with different calculation methods. Automated CCF determination may prove sufficient for evaluating CPR quality.

Keywords

Cardiopulmonary Resuscitation; Cardiopulmonary Arrest; Paramedic; Emergency Medical Services

INTRODUCTION

The delivery of chest compressions is an essential component of cardiopulmonary resuscitation.^{1,2} The American Heart Association currently recommends minimizing the frequency and duration of interruptions in chest compressions to maximize the number of compressions delivered per minute.¹ Chest compression fraction (CCF) has been associated with cardiac arrest outcomes. Christenson, et al. reported that increased CCF was independently associated with improved survival in out-of-hospital ventricular fibrillation arrests.³ Vaillancourt reported an association between CCF and return of spontaneous circulation in out-of-hospital cardiac arrests (OHCA) with non-shockable rhythms.⁴

Despite the prominence and perceived importance of CCF, standard methods for the determination of CCF have not been defined. While commercial software often report CCF for the entire patient encounter, individual studies have reported manually-calculated CCF for shorter time intervals. Standardizing CCF definitions is important to ensure consistent inferences across studies and with patient outcomes.

The objective of this study was to compare different methods for the determination of CCF in a cohort of OHCA.

METHODS

Study Design

We analyzed prospectively collected OHCA data from the Alabama site of the Resuscitation Outcomes Consortium (ROC). This study was approved by the Institutional Review Board of the University of Alabama at Birmingham.

Study Setting

ROC is a collaboration of 10 communities in the United States and Canada dedicated to the study of OHCA and severe traumatic injury. The larger ROC consortium encompasses a population of 23.7 million persons over a coverage area of 35,500 square miles and treats approximately 11,900 non-traumatic EMS-treated OHCA per year.⁵ The Alabama ROC site includes 10 EMS agencies in the greater Birmingham, Alabama area, encompassing a population of 650,000 persons over a 1,300 square miles area, and served by over 1,400 EMS personnel.

Data Source

The ROC Epistry is a prospective population-based registry of all cases of OHCA in the ROC communities.⁶ The registry includes individuals of all ages, including both treated and untreated cardiac arrests. At the Alabama ROC site, initial OHCA case identification occurred through prospective paramedic reports to a central call center. We supplemented call center case identification by review of EMS patient care records for each of the participating agencies. We matched all OHCA reports with the corresponding paramedic patient care report, 9-1-1 dispatch log, and hospital records. The hospital records were

limited to final vital status; Emergency Department and other clinical records were not available.

As part of Epistry, EMS providers submitted electronic cardiac monitor data, which included CPR chest compression data. EMS providers in this analysis used LifePak 12 (Physio Control, Inc., Redmond, Washington) cardiac monitors which identify chest compressions through changes in electrical impedance across the chest electrodes. In conformance with standard ROC-wide approaches, we used standard commercial software (CodeStat 8.0, Physio Control, Inc., Redmond, Washington) to process and organize the chest compression data.

Selection of Patients

This study included consecutive adult (age ≥ 19 years) OHCA treated by Alabama ROC EMS agencies during January 1, 2010 through October 28, 2010. We limited the analysis to cases treated by six EMS agencies where CPR process data were available (Bessemer Fire Department, Birmingham Fire and Rescue, Center Point Fire District, Hoover Fire Department, Rocky Ridge Fire District and Vestavia Hills Fire Department).

Data Analysis

We defined CCF as the proportion of a given time period with delivery of CPR chest compressions. Per standard ROC operational practices, chest compression interruptions consisted of time periods ≥ 3 seconds without chest compressions. We determined CCF using several methods based upon the commercial software, previously published literature, operational guidelines for ROC, and alternate approaches developed by the study team.^{3,4} The index standard (Method 1) consisted of automated CCF calculation as reported by the commercial software for the entire resuscitation episode; the software automatically excluded intervals where the monitor was disconnected or where the analyzable portion was shorter than ten seconds.

For the other methods (Methods 2-9), we parsed the CPR process file into 1-minute epochs, manually calculating the CPR CCF for each minute and calculating the average CCF across the selected epochs. (Table 2) For example, for Method 2, the reviewer would visually examine the CPR compression report for minute interval 1, calculating the appropriate CCF. The reviewer would then repeat the process for minute intervals 2 and 3. The reported CCF would consist of the average of CCF for minute intervals 1, 2 and 3. This process is the standard procedure performed for all ROC CPR process files.

To minimize the total number of statistical comparisons, we decided *a priori* to define automated CCF calculation (Method 1) as the index standard, comparing all CCF calculations to this figure. To compare CCF, we performed paired t-tests with a Bonferroni-adjusted p-value of 0.006 (accounting for 8 comparisons, corresponding to a 99.5% confidence interval). Because we hypothesized “equivalence” (vs. superiority) between different CCF calculation methods, in a sensitivity analysis we repeated the comparisons without Bonferroni adjustments. We performed all analyses using Stata v.12 (Stata, Inc, College Station, Texas).

RESULTS

CPR process data were available for 102 patients. Mean patient age was 60.3 years. (Table 1) Most were African American and male. Mean CPR duration was over 12 minutes. One-fourth presented with a shockable rhythm. Return of spontaneous circulation occurred in over 17%, and 8.8% survived to hospital discharge.

Using Method 1 (automated CCF calculation), the mean CCF across all episodes was 0.587 (99.5% CI: 0.554-0.620). (Table 2, Figure) With the exception of Method 7, the differences between Method 1 and the other CCF methods were not statistically significant. Method 7 resulted in a CCF slightly lower than Method 1. CCF Methods 4-9 were strongly correlated with Method 1.

In a sensitivity analysis we repeated the comparisons between CCF methods without a Bonferroni adjustment, finding largely similar results. (Appendix) While Method 8 (first half of episode) was now statistically different from automated CCF, the difference was not clinically significant (mean difference -2.8%).

DISCUSSION

While prior studies have described CPR CCF and their associations with patient outcomes, the approach to determining CCF has not been standardized.^{3,4} In this study we evaluated nine different methods for calculating CCF. Compared with the automated CCF calculation, we found only minimal differences using other manually-based approaches to CCF determination. Even if the CCF differences were found to be statistically significant, the values (mean CCF difference 0.004-0.054) would not be considered clinically significant.

Prior studies have described associations between CPR CCF and OHCA outcomes but used differing CCF calculation methodologies. Using data from the ROC, Christenson, et al. identified an association between CCF and survival after ventricular fibrillation/ventricular tachycardia (VF/VT) OHCA; in this study the authors defined CCF using the last 3 minutes of CPR prior to first shock.³ In contrast, Vaillancourt, et al. identified a tendency between increased CCF and increased return of spontaneous circulation among non-VF/VT OHCA, an analysis based upon the first 5 minutes of CPR.⁴ In yet another analysis with ROC data, Cheskes, et al. found that peri-shock CPR pauses (interruptions in CPR before and after rescue shock) were associated with worsened OHCA survival.⁷ Studies by Kramer-Johansen, et al. and Olsson et al. examined CCF for the entire care episode but did not draw associations with patient outcomes.^{8,9}

The findings of our study suggest that the CCF may be relatively robust to the method of calculation. This observation has important scientific and operational implications. Currently, under the assumption that automated CCF determinations are inaccurate, the ROC sites perform manual interpretation of CCF for each of the first 10 minutes of CPR chest compressions. The arduous nature of this process necessitates limiting analysis to a select time period. However, we found that various methods of manual CCF calculation resulted in figures similar to the automated CCF calculation for the entire care episode. If validated, this finding would indicate that manual interpretation of CPR CCF is unnecessary.

A potential explanation is that the CCF observed in shorter segments of CPR may be representative of CPR performance across the entire episode of care. While one might expect decay in CCF over the duration of resuscitation, current emphasis on improved resuscitation team dynamics and frequent changes in CPR personnel may have mitigated any CCF changes. We emphasize that this study was not specifically designed to examine CCF decay. We did observe that CCF was slightly lower with Method 7 (CPR start to first shock), a finding most likely due to CPR pauses for resuscitation tasks such as IV insertion and intubation. However, our analysis suggests that CPR interruptions from discrete tasks may ultimately prove minimal (less than 5%) compared with overall CPR continuity.

We emphasize that our analysis did not assess associations between each CCF calculation method and patient outcomes. For example, CCF in the early care may have different associations with patient outcomes than later CPR CCF, regardless of the consistency of the

figures. This and prior studies also did not evaluate other dimension of CPR quality such as compression rate and depth.^{3,4,7} Assessment of the relationships between different CCF measurements, CPR quality and patient outcomes is an important future step for validating the findings of this study.

LIMITATIONS

The CCF observed in this series was relatively low compared with other ROC sites and other published studies.^{8,9} However, replication with data of higher average CCF would result in lesser relative difference between CCF calculation methods. Conversely, replication with data of lower average CCF may result in larger relative CCF differences.

We used data from electrical-impedance-based chest compression detection; measurement using accelerometer-based systems may have yielded different results.¹⁰ We were unable to distinguish CPR delivered by basic life support versus advanced life support rescuers; CPR quality may have differed between these different providers. While periods without chest compression data would not be analyzable, there were very few such periods in our sample. We did not study inter-rater reliability of CCF calculation.

We studied nine hypothetical approaches to CCF calculation, but other methods are also possible. To simplify the analysis, we compared all CCF methods to automated CCF calculation only, without comparison between other methods. We decided *a priori* not to carry out the latter comparisons because their utility was less certain.

CONCLUSIONS

Compared with automated CCF determination for the entire care episode, there are minimal differences among manually-based CCF calculation methods using shorter time epochs. Automated CCF determination may be sufficient for evaluating CPR quality.

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Appendix

APPENDIX:

Comparison of chest compression fraction (CCF) calculation methods – no Bonferroni correction for repeated comparisons. (Confidence intervals changed from 99.5% to 95%) Differences from Method 1 determined using paired t-tests.

CCF Calculation Method	Mean (95% CI)	Mean Difference from Method 1 (95% CI)
1 – Automated CCF for entire care episode	0.587 (0.554-0.620)	N/A
2 – First 3 minutes of episode	0.526 (0.468-0.583)	-0.054 (-0.105 – 0.020)
3 – First 5 minutes of episode	0.541 (0.490-0.592)	-0.042 (-0.086 – 0.003)

CCF Calculation Method	Mean (95% CI)	Mean Difference from Method 1 (95% CI)
4 – First 10 minutes of episode	0.566 (0.530-0.603)	-0.017 (-0.036 – 0.002)
5 – Entire episode <i>excluding</i> first 5 minutes	0.562 (0.522-0.602)	-0.014 (-0.035 – 0.007)
6 – <i>Last</i> 5 minutes of episode	0.597 (0.557-0.637)	0.013 (-0.012 – 0.038)
7 – CPR start to first shock	0.530 (0.484-0.575)	-0.057 (-0.087 – (-)0.028)
8 – First half of episode	0.550 (0.512-0.589)	-0.028 (-0.055 – (-)0.002)
9 – Last half of episode	0.590 (0.548-0.633)	0.004 (-0.019 – 0.026)

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FIGURE.

Chest compression fraction (CCF) and 95% confidence intervals using different calculation methods. CCF calculation methods: 1) mean CCF for the entire patient care episode (automated calculation by manufacturer software), 2) mean CCF for first 3 minutes of patient care, 3) mean CCF for first 5 minutes, 4) mean CCF for first 10 minutes, 5) mean CCF for the entire episode except first 5 minutes, 6) mean CCF for last 5 minutes, 7) mean CCF from start to first shock, 8) mean CCF for the first half of resuscitation, 9) mean CCF for the second half of resuscitation.

TABLE 1

Patient characteristics.

Characteristic	N (%)
Age - mean years (95% CI) [range]	60.3 (56.1-64.4) [0.25-99]
Sex	
Male	65 (63.7)
Female	37 (36.3)
Race	
African American	58 (56.9)
White	36 (35.3)
Hispanic	1 (1.0)
Unknown	7 (6.9)
Initial Rhythm	
Shockable rhythm (VF/VT)	24 (23.5)
Other Rhythms (PEA/Asystole)	78 (76.5)
CPR duration mean (95% CI) [range]	728 seconds (647-809) [21-2,170]
Return of Spontaneous Circulation	
Yes	18 (17.6)
No	84 (82.4)
Outcomes	
Death in field	8 (7.8)
Death in Emergency Department	65 (63.7)
Death in Intensive Care Unit	16 (15.7)
Death in Operating Room	1 (1.0)
Survival to Hospital Discharge	9 (8.8)
Unknown	3 (2.9)

TABLE 2

Comparison of chest compression fraction (CCF) calculation methods. Differences from Method 1 determined using paired t-tests. (99.5% confidence intervals for paired differences reflect Bonferroni adjustment for eight comparisons.)

CCF Calculation Method	Mean (95% CI)	Mean Difference from Method 1 (99.5% CI)	Correlation with Method 1 (ρ)
1 – Automated CCF for entire care episode	0.587 (0.554-0.620)	N/A	N/A
2 – First 3 minutes of episode	0.526 (0.468-0.583)	-0.054 (-0.128 – 0.021)	0.48
3 – First 5 minutes of episode	0.541 (0.490-0.592)	-0.042 (-0.106 – 0.022)	0.52
4 – First 10 minutes of episode	0.566 (0.530-0.603)	-0.017 (-0.045 – 0.010)	0.85
5 – Entire episode <i>excluding</i> first 5 minutes	0.562 (0.522-0.602)	-0.014 (-0.045 – 0.016)	0.85
6 – <i>Last</i> 5 minutes of episode	0.597 (0.557-0.637)	0.013 (-0.023 – 0.049)	0.78
7 – CPR start to first shock	0.530 (0.484-0.575)	-0.057 (-0.100 – (-)0.014)	0.76
8 – First half of episode	0.550 (0.512-0.589)	-0.028 (-0.067 – 0.100)	0.74
9 – Last half of episode	0.590 (0.548-0.633)	0.004 (-0.029 – 0.036)	0.85