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Compression-to-Ventilation Ratio and Incidence of Rearrest – A Secondary Analysis of the ROC CCC Trial

David D. Salcido, PhD*, **Robert H. Schmicker, MS**, **Jason E. Buick, MS**, **Sheldon Cheskes, MD**, **Brian Grunau, MD**, **Peter Kudenchuk, MD**, **Brian Leroux, PhD**, **Stephanie Zellner, BS**, **Dana Zive, MPH**, **Tom P. Aufderheide, MD**, **Allison C. Koller, BS**, **Heather Herren, MPH**, **Jack Nuttall, MS**, **Matthew L. Sundermann, MS**, **James J. Menegazzi, PhD**, and **The Resuscitation Outcomes Consortium Investigators**

[1]University of Pittsburgh, Pittsburgh, PA

[2]University of Washington, Seattle, WA

[3]University of Toronto, Toronto, ON

[4]Sunnybrook Center for Prehospital Medicine, Toronto, ON

[5]University of British Columbia, Vancouver, BC

[6]Medical College of Wisconsin, Milwaukee, WI

[7]Oregon Health Sciences University, Portland, OR

Abstract

Background—Previous work has demonstrated that when out-of-hospital cardiac arrest (OHCA) patients achieve return of spontaneous circulation (ROSC), but subsequently have another cardiac arrest prior to hospital arrival (rearrest), the probability of survival to hospital discharge is significantly decreased. Additionally, few modifiable factors for rearrest are known. We sought to examine the association between rearrest and compression-to-ventilation ratio during cardiopulmonary resuscitation (CPR) and to confirm the association between rearrest and outcomes.

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*Corresponding author: David D. Salcido, PhD, 3600 Forbes Ave, Iroquois Building, Suite 400A, Pittsburgh, PA 15261, Phone: 412-683-7169, salcidodd@upmc.edu.

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Hypothesis—Rearrest incidence would be similar between cases treated with 30:2 or continuous chest compression (CCC) CPR, but inversely related to survival and good neurological outcome.

Methods—We conducted a secondary analysis of a large randomized-controlled trial of CCC versus 30:2 CPR for the treatment of OHCA between 2011 and 2015 among 8 sites of the Resuscitation Outcomes Consortium (ROC). Patients were randomized through an emergency medical services (EMS) agency-level cluster randomization design to receive either 30:2 or CCC CPR. Case data were derived from prehospital patient care reports, digital defibrillator files, and hospital records. The primary analysis was an as-treated comparison of the proportion of patients with a rearrest for patients who received 30:2 versus those who received CCC. In addition, we assessed the association between rearrest and both survival to hospital discharge and favorable neurological outcome (Modified Rankin Score ≤ 3) in patients with and without ROSC upon ED arrival using multivariable logistic regression adjusting for age, sex, initial rhythm and measures of CPR quality.

Results—There were 14,109 analyzable cases that were determined to have definitively received either CCC or 30:2 CPR. Of these, 4,713 had prehospital ROSC and 2,040 (43.2%) had at least one rearrest. Incidence of rearrest was not significantly different between patients receiving CCC and 30:2 (44.1% vs 41.8%; adjusted OR: 1.01; 95% CI: 0.88, 1.16). Rearrest was significantly associated with lower survival (23.3% vs 36.9%; adjusted OR: 0.46; 95%CI: 0.36–0.51) and worse neurological outcome (19.4% vs 30.2%; adjusted OR: 0.46; 95%CI: 0.38, 0.55).

Conclusion—Rearrest occurrence was not significantly different between patients receiving CCC and 30:2, and was inversely associated with survival to hospital discharge and MRS.

Keywords

Out-of-Hospital Cardiac Arrest; Clinical Trials

Background

In the analysis of the prehospital treatment of out-of-hospital cardiac arrest (OHCA), it is useful to demarcate between the periods prior to and after achievement of return of spontaneous circulation (ROSC) and the risks inherent to either. Prior to ROSC, accumulated no-flow time, sub-physiological blood flow from CPR, and delays to defibrillation are among the many detrimental factors working against the patient regaining pulses and subsequently surviving neurologically intact.[1] Following ROSC, the most proximal risk to the patient survival is secondary cardiac arrest, or *rearrest*, prior to hospital arrival. Rearrest may present with any of the gross electrocardiogram (ECG) presentations of cardiac arrest, including ventricular fibrillation / ventricular tachycardia (VF/VT), pulseless electrical activity, and asystole. Previous studies have shown that rearrest occurs in 5% to 39% of all cases achieving ROSC and is associated with reduced probability of survival to hospital discharge. [2–6] Considering this, prevention or prediction of rearrest could present a significant opportunity to increase survival after OHCA. However, to date there is little evidence for predicting prehospital rearrest, either by patient characteristics or procedural factors.

Compression-to-ventilation ratio (CVR) is a procedural factor of resuscitation describing the ratio of time delivering compressions to time delivering ventilations in a given bout of CPR. CVR has been investigated as a modifiable factor in the improvement of resuscitation outcomes, and there is accumulated evidence that a CCC approach to CPR, minimizing or eliminating pauses for ventilations, may be superior hemodynamically and in clinical outcome.[7–9] There is sparse and contradictory evidence that chest compressions may induce refibrillation,[10–12] however it is not clear whether specific CVRs favor or inhibit the hypothesized mechanisms for this phenomenon. In a recent large randomized controlled trial of continuous chest compressions (CCC) versus interrupted 30:2 chest compressions (ICC), the Resuscitation Outcomes Consortium (ROC) investigated the association between CVR and key resuscitation outcomes, resulting in the finding of no general association between CVR and survival or neurologic function.[13] However, the primary analyses of this trial did not consider rearrest as an outcome, leaving important unanswered questions about rearrest, its effects, and its potential causes. Therefore, we conducted this secondary analysis of the ROC CCC v. 30:2 trial. We specifically investigated the association between the incidence of rearrest and CVR, as well as the association between rearrest and both survival to hospital discharge and neurologic function when controlling for CVR.

Methods

Parent Clinical Trial

This study was conducted under existing IRB protocols applicable to the ROC CCC v. 30:2 trial as well as secondary analyses thereof. All analyses were conducted retrospectively. The population, design, and results of the primary analyses of the ROC CCC v. 30:2 trial have been reported elsewhere.[13–14] In brief, the ROC is a research network conducting OHCA surveillance and clinical trials in acute resuscitation care with 10 clinical sites in the United States and Canada.[15] The ROC CCC v. 30:2 trial cluster randomized participating emergency medical services (EMS) agencies at 8 participating sites to deliver CCC or 30:2 CPR manually to OHCA patients as part of standardized resuscitation protocols, with twice annual group crossover. EMS transit and event timing, patient characteristics and outcomes, treatments and treatment timing, and resuscitation process quality metrics were recorded throughout the trial in standardized, web-based electronic data forms with data abstracted manually from EMS patient care reports, digital defibrillator downloads, and hospital records by ROC site-level data abstractors following standardized data entry protocols.

Inclusion – Exclusion Criteria

The present study cohort included cases of non-traumatic EMS-treated OHCA from all ROC sites participating in the ROC CCC v. 30:2 trial, and spanned the full trial period June 2011–May 2015. To be included in analyses, cases had to have evidence of a prehospital ROSC event, a definitive classification of the CPR delivered as either CCC or 30:2 CPR, and non-missing rearrest status.

CVR Detection Algorithm

While EMS agencies were randomized to deliver either CVR for discrete periods of time during the trial, the actual CVR delivered did not always correspond to the randomly prescribed CVR due to unpredictable protocol deviation at the provider level. Therefore, for the sake of the present study, CVR for each case was determined through automated analysis of abstracted CPR process data. Detailed methods of the algorithm have been reported elsewhere.[16] In brief, three metrics were determined to be important in distinguishing between the two protocols: compression segment length, number of pauses and chest compression fraction. To be classified as CCC, two of three metrics had to be met: chest compression fraction (CCF) > 0.75, median compression segment >90 seconds, <1 pauses per minute. For 30:2 CPR, the metrics were: CCF 0.60 – 0.75, median compression segment <20 seconds, 2–4 pauses per minute. Cases that did not meet two of three criteria for either treatment were classified as indeterminate and excluded from the analysis.

Outcomes

Included among abstracted data points were patient outcomes, including ROSC, survival to hospital discharge, Modified Rankin Scale (MRS), and a binary indicator of any rearrest. ROSC was defined as any apparent return of pulses based on all available evidence, and ascertained from patient care reports and defibrillator tracings. Survival to hospital discharge was defined as discharge from the hospital alive to home or long term care facility, and was ascertained through hospital records. Good neurological function at hospital discharge was defined as an MRS score of less than or equal to 3, determined from hospital records according to standardized evaluation criteria.

Analysis

Rearrest rate was calculated as the proportion of cases with rearrest among cases with ROSC both overall and stratified by CVR group. Rearrest rate was compared between CVR groups and also across the years of the study and the participating sites of the ROC. CPR process characteristics, including rate, depth, chest compression fraction (CCF), and pre-/post-shock pauses, were compared between cases with and without rearrest.

The associations between rearrest occurrence and resuscitation outcomes of survival to hospital discharge and MRS were evaluated in separate multivariable logistic regression models. Each model contained the covariates rearrest status, sex, age >= 60, bystander witnessed status, bystander CPR status, public location of OHCA, cardiac etiology, initial rhythm (VT/VF, PEA, Asystole, No Shock), time to EMS arrival >= 6min, time to ROSC >= 30min, CPR fraction > 0.9, case average chest compression rate, and individual site-level indicator variables. Furthermore, in order to more directly understand the influence of rearrest on survival and neurologic status, we repeated these analyses including only those patients who had recovered ROSC at ED arrival. Lastly, a similar multivariable logistic regression model was also constructed to assess the association between CVR and rearrest, while adjusting for potential confounders.

Data management and analyses were conducted using S-Plus version 6.2.1 (TIBCO Software Inc. Palo Alto, California, USA), and Stata version 11 (StataCorp, College Station, Texas, USA). An alpha level of 0.05 was used as the criterion for statistical significance for all analyses.

Results

While the active enrollment phase total for the parent trial was 23,711**,** a total of 9,601 cases were excluded from this secondary analysis due to unclassifiable CVR. Of the remaining 14,109 cases classified as either CCC or 30:2 CPR, 4,713 (33.4%) had prehospital ROSC. Table 1 shows the characteristics of cases overall and stratified by rearrest and ROSC status. Rates of ROSC varied between 19.2% and 53.4% across the 8 participating sites ($p<0.001$). Among cases with ROSC, 2,040 (43.3%) had at least one rearrest event. Rates of rearrest varied from 32.1% to 46.5% across sites ($p < 0.01$). Averaged across all sites, rearrest rates ranged from 40.6% to 45.8% from 2012 to 2015 ($p=0.64$), where 2011 was excluded from rate trend analysis due to trial ramp up (Table 2).

Among cases with rearrest, the most frequent presenting rhythm for the primary OHCA was asystole. Rates of rearrest differed by presenting rhythm ($p<0.001$), with the highest proportion of rearrest in cases presenting with asystole (49.8%) and the lowest among cases presenting with VF/VT (39.0%), while pulseless electrical activity (PEA) and no-shock advised rhythm classifications had similar rearrest rates (42.6% vs. 45.7%). CPR process characteristics are shown in Table 3 stratified by rearrest status. Chest fraction ($p < 0.001$), compression depth ($p = 0.03$), and compression rate ($p = 0.03$) differed between cases with and without rearrest but in clinically insignificant magnitudes.

Cases randomized to the CCC treatment arm were more likely to experience a rearrest event than cases in the 30:2 CPR arm (44.7% vs 42.2%; OR: 1.10; 95% CI: 1.03, 1.18). When the CVR classification algorithm was applied, the as-treated group allocation was 9,318 (66.0%) CCC and 4,791 (34.0%_ 30:2 CPR. In the as-treated analysis, there was a difference in rearrest rate between CCC and 30:2 (44.1% vs 41.8%; OR: 1.10; 95% CI: 1.00, 1.21). On further investigation, adjustment for several covariates in a multivariable logistic regression model with rearrest as outcome found no significant association between as-randomized CVR and rearrest (OR 1.01; 95% CI: 0.88, 1.16), shown in Table 4. Characteristics that demonstrated a statistically significant association with rearrest included age, sex, etiology of the primary cardiac arrest and presenting ECG rhythm.

Lastly, in multivariable logistic regression models, rearrest was significantly inversely associated with survival to hospital discharge both when considering all patients and only those with a pulse at ED arrival (separate estimates shown in Table 5). In the same models, as-randomized CVR group was not associated survival or neurologic outcome.

Discussion

This study had two objectives. The first was to describe the incidence and outcomes of rearrest in a recent, large clinical trial, giving a contemporary picture of how rearrest manifested in the context of the 2010 resuscitation guidelines. Rearrest is common, and relative to previous estimates derived from older ROC data, may be more common than previously demonstrated. An estimate of rearrest incidence derived from 2008 – 2011 showed that between 16.5% and 38.4% of all cases with ROSC developed a rearrest prior to hospital arrival.[6] Unlike the present study, the older study did not benefit from specific rearrest data fields in ROC data forms, and a large portion of rearrest ascertainment involved secondary inference. We did not find a significant temporal trend in rearrest incidence, however we did find a significant difference in rearrest incidence between the ROC sites. The latter finding is not unexpected given findings from earlier periods of the ROC demonstrating significant variability in OHCA incidence, survival and characteristics between the sites.[20–21] On the other hand, there was not strong basis for expecting a temporal trend in rearrest incidence specifically, as to our knowledge this was the first such analysis concerning rearrest over time.

We also found rearrest to be inversely associated with both survival to hospital discharge and post-resuscitation neurologic function. Our previous work similarly found rearrest to be inversely related to survival, with nearly 80% greater odds of death prior to hospital discharge.[6] Estimates of the association between rearrest and survival in the present study were similar when considering patients with ROSC at any time, but were tempered when limited to just those patients who arrived at the emergency department with pulses.

The mechanisms underlying the relationship between rearrest and survival are unclear. Rearrest is a secondary whole-body ischemic insult following rapidly (i.e., prior to hospital arrival) upon the heels of the primary insult. It is not known if the cumulative duration of all downtime, including the primary arrest and rearrests, has an additive deleterious effect on organ systems, but to this end Berdowski showed previously that cumulative time in recurrent VF at least has a negative impact on neurologically intact survival.[22] The alternative, equally plausible, is that rearrest is a manifestation of pre-existing conditions of a patient who is likely to do poorly downstream regardless of the rearrest. The fact that those who had a presenting ECG rhythm of asystole were far more likely to rearrest supports this assertion, as it is likely that they had a more prolonged ischemic insult prior to ROSC. In this study the association between rearrest and post-admission outcomes was assessed with adjustment for several factors known to correlate with outcome. Unfortunately, critical information about patient history was not part of this adjustment, and so uncertainty remains about mechanism. It seems likely that rearrest may be both cause and effect depending on the circumstances of the primary and secondary arrests.

The second aim of this study was to assess the relationship of rearrest to CPR, specifically considering CVR. Mechanistically, one could have hypothesized that increased no-flow time in 30:2 CPR might be physiologically deleterious for patients and predispose them to a secondary arrest after ROSC. Low chest compression fraction and longer perishock pause intervals, 2 examples of intra-CPR no-flow time, have been shown to correlate with poor outcomes.[17–19] Conversely, CCC limits opportunities for rhythm assessment during resuscitation and requires ventilations to be delivered without pause. With respect to the former, it is possible that less frequent rhythm analysis may lead to increased probability of chest compressions delivered over a beating heart which may worsen outcomes. That said, in the most direct assessment of this relationship in the present study, considering as-treated CVR, rearrest rates did not differ between cases treated with CCC and 30:2 ICC, when adjusting for important resuscitation covariates.

This study has several limitations that must not be overlooked when evaluating its findings. First, the accuracy of ascertainment of rearrest is directly related to the resolution of the data available. In this study, as in previous studies that have sought to capture rearrest, the determination of rearrest is limited to prehospital medical records and defibrillator signals. Neither of these sources can be considered definitive in all contexts, owing to differential reporting practices and signal feature ambiguity, respectively. Second, the key independent variable in this study was case level CVR, but in practice randomized CVR was often applied with highest certitude during the initial stages of resuscitation, diminishing thereafter. Many cases may have received both CVRs during the course of resuscitation, and so the effect of CVR on rearrest can only be considered uniformly across all cases with respect to its acute early phase administration. Lastly, while an association was observed between any rearrest and both survival and neurological outcomes, including among patients admitted to hospital, it is not known if or how pre-arrest patient characteristics, medications, or pathology contributed to either the rearrest or subsequent outcomes.

Conclusions

In the ROC CCC v. 30:2 trial, rearrest was relatively common and inversely associated with survival to hospital discharge and good neurologic function. Rearrest was not independently associated with as-treated CVR group.

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Table 1

Descriptive Statistics by Rearrest and ROSC Status

Case characteristics are summarized and stratified by prehospital rearrest and ROSC status, as well as overall.

	Rearrest	ROSC no Rearrest	No ROSC	Overall
n	2040	2673	9396	14109
Male, n (%)	1363 (66.8%)	1650 (61.7%)	5991 (63.8%)	9004 (63.8%)
Age				
Median (IQR)	69.0 (22.0)	65.0 (23.0)	68.0 (26.0)	68.0 (25.0)
<40 yrs, n (%)	111 (5.4%)	219 (8.2%)	674 (7.2%)	1004 (7.1%)
40–60 yrs, n (%)	502 (24.6%)	748 (28.0%)	2361 (25.1%)	3611 (25.6%)
>60 yrs, n (%)	1427 (70.0%)	1706 (63.8%)	6361 (67.7%)	9494 (67.3%)
Witness Status				
Bystander, n (%)	1175 (57.6%)	1647 (61.6%)	3128 (33.3%)	5950 (42.2%)
None, n (%)	865 (42.4%)	1026 (38.4%)	6268 (66.7%)	8159 (57.8%)
Bystander CPR, n (%)	1060 (52.0%)	1439 (53.8%)	4172 (44.4%)	6671 (47.3%)
Initial rhythm				
VT/VF, n (%)	670 (32.8%)	1117 (41.8%)	1348 (14.3%)	3135 (22.2%)
PEA, n (%)	531 (26.0%)	688 (25.7%)	1607 (17.1%)	2826 (20.0%)
Asystole, n (%)	746 (36.6%)	738 (27.6%)	5937 (63.2%)	7421 (52.6%)
No shock advised, n (%)	93 (4.6%)	130 (4.9%)	504 (5.4%)	727 (5.2%)
Episode location				
Public, n (%)	307 (15.1%)	573 (21.5%)	1046 (11.1%)	1926 (13.7%)
Private, n (%)	1731 (84.9%)	2097 (78.5%)	8345 (88.9%)	12173 (86.3%)
First agency arrival time				
<6 minutes, n (%)	1137 (55.7%)	1618 (60.5%)	5575 (59.3%)	8330 (59.0%)
>= 6 minutes, n (%)	903 (44.3%)	1055 (39.5%)	3821 (40.7%)	5779 (41.0%)
Randomized CCC Treatment Arm				
CCC, n (%)	1175 (57.6%)	1449 (54.2%)	5330 (56.7%)	7954 (56.4%)
30:2, n (%)	865 (42.4%)	1224 (45.8%)	4066 (43.3%)	6155 (43.6%)
As-treated CCC Arm				

	Rearrest	ROSC no Rearrest	No ROSC	Overall
CCC, n (%)	1330 (65.2%)	1684 (63.0%)	6304 (67.1%)	9318 (66.0%)
30:2, n (%)	710 (34.8%)	989 (37.0%)	3092 (32.9%)	4791 (34.0%)
Site				
A, n (row %)	45 (2.2%)	91 (3.4%)	324 (3.4%)	460 (3.3%)
B, n (row %)	165 (8.1%)	225 (8.4%)	1644 (17.5%)	2034 (14.4%)
C, n (row %)	18 (0.9%)	38 (1.4%)	207 (2.2%)	263 (1.9%)
D, n (row %)	305 (15.0%)	477 (17.8%)	682 (7.3%)	1464 (10.4%)
E, n (row %)	202 (9.9%)	234 (8.8%)	704 (7.5%)	1140 (8.1%)
F, n (row %)	444 (21.8%)	525 (19.6%)	1199 (12.8%)	2168 (15.4%)
G, n (row %)	610 (29.9%)	698 (26.1%)	3039 (32.3%)	4347 (30.8%)
H, n (row %)	251 (12.3%)	385 (14.4%)	1597 (17.0%)	2233 (15.8%)

Abbreviations: CCC – Continuous Chest Compressions, IQR – Interquartile Range, PEA – Pulseless Electrical Activity, ROSC – Return of Spontaneous Circulation, VF/VT – Ventricular Fibrillation / Ventricular Tachycardia

Table 2

Rearrest Rates by ROC Site and Year

Rearrest and ROSC rates are shown stratified by year and anonymized ROC site. Note that site anonymization is different in this table to disassociate temporal trends from model patterns to preserve site anonymity.

Site	2012	2013	2014	2015	Overall
	ROSC / Rearrest	ROSC / Rearrest	ROSC / Rearrest	ROSC / Rearrest	ROSC / Rearrest
A	28.5% / 29.7%	25.3% / 33.3%	35.7% / 34.8%	31.4% / 36.4%	29.6% / 33.1%
B	18.2% / 45.2%	20.0% / 42.6%	19.2% / 40.3%	18.8% / 42.3%	19.2% / 42.3%
C	21.2% / 23.8%	21.7% / 22.2%	17.8% / 46.2%	50.0% / 75.0%	21.3% / 32.1%
D	51.9% / 36.5%	53.0% / 37.4%	54.0% / 39.1%	55.5% / 46.2%	53.4% / 39.0%
E	40.5% / 41.1%	36.8% / 48.8%	39.3% / 46.2%	33.6% / 54.5%	38.2% / 46.3%
F	45.1% / 45.1%	43.8% / 45.3%	47.3% / 47.4%	39.3% / 44.6%	44.7% / 45.8%
G	27.8% / 42.0%	31.1% / 46.9%	30.8% / 49.5%	30.4% / 45.8%	30.1% / 46.6%
H	27.6% / 36.6%	29.3% / 38.6%	27.8% / 40.3%	29.8% / 44.2%	28.5% / 39.5%
Overall	32.8% / 40.6%	33.7% / 42.9%	34.2% / 44.4%	32.6% / 45.8%	33.4% / 43.3%

Abbreviations: ROSC – Return of Spontaneous Circulation

Table 3

CPR Process Measures by Rearrest Status

CPR process measures are summarized and stratified by prehospital rearrest and ROSC status, as well as overall.

	Rearrest, Before ROSC	ROSC, No Rearrest	Overall
n	2040	2673	4713
Available minutes, mean (SD)	8.6 (3.5)	7.9 (3.3)	8.4 (3.3)
CCF	n=2000	n=2673	n=4713
Mean (SD)	0.84 (0.09)*	0.83 (0.10)	0.83 (0.10)
<=0.40, n (%)	3 (0.2%)	3 (0.1%)	5 (0.1%)
0.41–0.60, n (%)	14 (0.7%)	28 (1.0%)	54 (1.1%)
0.61–0.80, n (%)	589 (29.5%)	878 (32.8%)	1514 (32.1%)
>0.80, n (%)	1394 (69.7%)	1764 (66.0%)	3140 (66.6%)
Compression Rate, CPM	n=1967	n=2673	n=4712
Mean (SD)	109.2 (9.8)**	109.9 (10.5)	109.6 (10.2)
<100, n (%)	300 (15.3%)	396 (14.8%)	711 (15.1%)
100–120, n (%)	1414 (71.9%)	1860 (69.6%)	3323 (70.5%)
>120, n (%)	253 (12.9%)	417 (15.6%)	678 (14.4%)
Compression Depth, mm	n=1065	n=1428	n=2533
Mean (SD)	49.9 (11.5)**	48.9 (10.9)	49.3 (11.2)
<37, n (%)	135 (12.7%)	194 (13.6%)	340 (13.4%)
37–51, n (%)	462 (43.4%)	640 (44.8%)	1107 (43.7%)
>51, n (%)	468 (43.9%)	594 (41.6%)	1086 (42.9%)
Pre-Shock Pause, s	n=713	n=1123	n=1867
Mean (SD)	10.9 (9.4)	10.7 (9.5)	10.8 (9.5)
<10, n (%)	367 (51.5%)	571 (50.8%)	953 (51.0%)
10–20, n (%)	253 (35.5%)	413 (36.8%)	682 (36.5%)
>20, n (%)	93 (13.0%)	139 (12.4%)	232 (12.4%)
Post-Shock Pause, s	n=712	n=1114	n=1852
Mean (SD)	4.7 (3.5)	4.9 (4.9)	4.9 (4.6)

	Rearrest, Before ROSC	ROSC, No Rearrest	Overall
<10, n (%)	666 (50.2%)	1040 (66.7%)	1728 (60.4%)
10–20, n (%)	40 (5.6%)	59 (5.3%)	100 (5.4%)
>20, n (%)	6 (0.8%)	15 (1.3%)	24 (1.3%)
Number of Shocks, mean (SD)	3.7 (2.9)	2.5 (2.0)	3.0 (2.5)

Superscripts: * - $p < 0.001$; **- $p < 0.05$

Abbreviations: CCF – Chest Compression Fraction, CPM – Compressions Per Minute, mm – millimeters, ROSC – Return of Spontaneous Circulation, s – seconds, SD – Standard Deviation

Table 4

Logistic Regression Results for Outcome Rearrest

Results, reported as Odds Ratios with 95% Confidence Intervals, are shown for the logistic regression model with outcome of rearrest using the set of patients with any ROSC during the prehospital phase of treatment.

Population	**ROSC in PH** **n = 4,676**
Outcome	**Rearrest (1=yes, 0=no)**
As Treated 30:2	reference
As Treated CCC	1.01 (0.88, 1.16)
Female	reference
Male	1.40 (1.23, 1.59)
Age <60	reference
Age >=60	1.22 (1.07, 1.39)
Bystander witnessed	reference
Not witnessed	1.03 (0.91, 1.17)
No bystander CPR	reference
Bystander CPR	1.06 (0.93, 1.20)
Private location	reference
Public location	0.74 (0.63, 0.87)
Cardiac etiology	reference
Noncardiac etiology	0.61 (0.42, 0.88)
Initial rhythm VT/VF	0.65 (0.56, 0.77)
Initial rhythm PEA	0.80 (0.68, 0.94)
Initial rhythm Asystole	reference
Initial rhythm No Shock	0.80 (0.59, 1.08)
Time to ROSC < 30 min	reference
Time to ROSC >= 30 min	1.54 (1.34, 1.79)
Time to 1st Agency Arrival <6 min	0.90 (0.80, 1.03)
Time to 1st Agency arrival >=6 min	reference
CCF before ROSC <0.90	reference

Population	ROSC in PH n = 4,676
Outcome	**Rearrest (1=yes, 0=no)**
CCF before ROSC >0.90	1.13 (0.98, 1.32)
Site A	reference
Site B	1.58 (1.02, 2.45)
Site C	1.03 (0.51, 2.07)
Site D	1.31 (0.87, 1.97)
Site E	1.70 (1.10, 2.62)
Site F	1.51 (1.01, 2.25)
Site G	1.73 (1.16, 2.57)
Site H	1.39 (0.92, 2.11)

Abbreviations: CCC – Continuous Chest Compressions, CCF – Chest Compression Fraction, CPR- Cardiopulmonary Resuscitation, PEA – Pulseless Electrical Activity, PH – Prehospital, ROSC – Return of Spontaneous Circulation, VF/VT – Ventricular Fibrillation / Ventricular Tachycardia

Table 5

Logistic Regression Results for Outcome Survival to Hospital Discharge and MRS

Results, reported as Odds Ratios with 95% Confidence Intervals, are shown for 4 multivariable logistic regression models covering 2 outcomes (Survival & Modified Rankin Score >=3) and 2 overlapping patient subsets (those with any ROSC in prehospital phase & those with ROSC at emergency department arrival).

Outcome	Survival		MRS<3	
Population	**ROSC in PH n=7332**	**ROSC at ED n=5362**	**ROSC in PH n=7282**	**ROSC at ED n=5315**
No prehospital Rearrest	reference	reference	reference	reference
Prehospital Rearrest	0.21 (0.18, 0.25)	0.43 (0.36, 0.51)	0.24 (0.20, 0.28)	0.46 (0.38, 0.55)
Female	reference	reference	reference	reference
Male	1.44 (1.24, 1.67)	1.47 (1.26, 1.72)	1.38 (1.18, 1.63)	1.38 (1.17, 1.64)
Age <60	reference	reference	reference	reference
Age >=60	0.43 (0.37, 0.49)	0.40 (0.35, 0.47)	0.38 (0.33, 0.45)	0.36 (0.31, 0.42)
Bystander witnessed	reference	reference	reference	reference
Not witnessed	0.63 (0.55, 0.73)	0.63 (0.54, 0.73)	0.62 (0.53, 0.74)	0.63 (0.53, 0.75)
No bystander CPR	reference	reference	reference	reference
Bystander CPR	1.11 (0.97, 1.28)	1.08 (0.93, 1.25)	1.14 (0.98, 1.32)	1.10 (0.94, 1.29)
Private location	reference	reference	reference	reference
Public location	1.81 (1.56, 2.11)	1.89 (1.60, 2.22)	2.03 (1.73, 2.38)	2.10 (1.77, 2.48)
Cardiac etiology	reference	reference	Reference	reference
Noncardiac etiology	1.89 (1.31, 2.71)	1.79 (1.23, 2.61)	1.75 (1.14, 2.68)	1.64 (1.06, 2.54)
Initial rhythm VT/VF	12.9 (10.3, 16.0)	12.4 (9.84, 15.6)	16.4 (12.4, 21.5)	15.7 (11.9, 20.8)
Initial rhythm PEA	3.05 (2.40, 3.86)	3.13 (2.45, 4.00)	3.28 (2.43, 4.43)	3.35 (2.46, 4.55)
Initial rhythm Asystole	reference	reference	reference	reference
Initial rhythm No Shock	2.48 (1.72, 3.58)	2.69 (1.85, 3.92)	2.65 (1.69, 4.15)	2.80 (1.77, 4.43)
Time to 1st Agency Arrival <6 min	1.01 (0.87, 1.16)	1.00 (0.86, 1.16)	1.11 (0.95, 1.29)	1.11 (0.94, 1.30)
Time to 1st Agency arrival >=6 min	reference	reference	reference	reference
Time to ROSC < 30 min	reference	reference	reference	reference
Time to ROSC >= 30 min	0.18 (0.14, 0.23)	0.19 (0.15, 0.25)	0.17 (0.13, 0.23)	0.18 (0.14, 0.24)

Outcome	Survival		MRS<3	
Population	**ROSC in PH n=7332**	**ROSC at ED n=5362**	**ROSC in PH n=7282**	**ROSC at ED n=5315**
CCF <0.90	reference	reference	reference	reference
CCF >0.90	0.98 (0.83, 1.16)	0.98 (0.82, 1.17)	0.86 (0.71, 1.04)	0.87 (0.71, 1.05)
Mean Compression Rate <100	reference	reference	reference	reference
Mean Compression Rate 100–120	0.85 (0.70, 1.04)	0.85 (0.69, 1.04)	0.88 (0.71, 1.09)	0.87 (0.69, 1.09)
Mean Compression Rate >120	0.95 (0.75, 1.21)	0.97 (0.75, 1.25)	0.94 (0.72, 1.22)	0.94 (0.72, 1.24)
Site A	reference	reference	reference	reference
Site B	1.00 (0.64, 1.57)	1.08 (0.66, 1.75)	0.87 (0.51, 1.50)	0.92 (0.52, 1.63)
Site C	0.47 (0.23, 0.96)	0.40 (0.19, 0.85)	0.70 (0.30, 1.62)	0.55 (0.22, 1.37)
Site D	1.24 (0.81, 1.88)	1.15 (0.74, 1.79)	1.89 (1.15, 3.11)	1.82 (1.08, 3.06)
Site E	1.24 (0.79, 1.96)	1.28 (0.79, 2.07)	1.45 (0.84, 2.50)	1.47 (0.83, 2.61)
Site F	1.03 (0.69, 1.56)	1.02 (0.66, 1.57)	2.35 (1.44, 3.84)	2.44 (1.46, 4.08)
Site G	0.70 (0.47, 1.05)	0.70 (0.46, 1.08)	1.63 (1.01, 2.65)	1.72 (1.03, 2.86)
Site H	0.78 (0.51, 1.19)	0.79 (0.50, 1.24)	1.62 (0.98, 2.68)	1.77 (1.04, 3.00)

Abbreviations: CCF – Chest Compression Fraction, CPR – Cardiopulmonary Resuscitation, ED – Emergency Department, MRS – Modified Rankin Score, PEA – Pulseless Electrical Activity, PH – Prehospital, ROSC – Return of Spontaneous Circulation, VF/VT – Ventricular Fibrillation / Ventricular Tachycardia