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Clinical paper

Lower chest compression fraction associated with ROSC in OHCA patients with longer downtimes☆

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ABSTRACT

Aim: To investigate the relationship between chest compression fraction (CCF) and survival outcomes in OHCA, including whether the relationship varied based upon downtime from onset of arrest to provision of cardiopulmonary resuscitation (CPR) by emergency medical services (EMS).
Methods: Data from resuscitations performed by St John Ambulance Western Australia (SJA-WA) paramedics between July 2014 and June 2016 was captured using the Q-CPR feedback device. Logistic regression analysis was used to study the relationship between CCF and return of spontaneous circulation (ROSC). Various lengths of Q-CPR data were used ranging from the first 3 min to all available episode data. Cases were subsequently divided into groups based upon downtime; ≤15 min, >15 min and unknown. Univariate and multivariable logistic regression analyses were performed in each group.
Results: There were 341 cases eligible for inclusion. CCF > 80% was significantly associated with decreased odds of ROSC compared to CCF ≤ 80% (aOR: 0.49, 95%CI: 0.28–0.87). This relationship remained significant whether the first 3 min of data was used, the first 5 min or all available episode data. Among the group with a downtime >15 min, CCF was significantly lower for those who achieved ROSC compared to those who did not (mean (SD): 73.01 (12.99)% vs. 83.05 (9.38)% p = 0.002). The adjusted odds ratio for achieving ROSC in this group was significantly less with CCF > 80% compared to CCF ≤ 80% (aOR: 0.06, 95%CI: 0.01–0.38).
Conclusion: We demonstrated an inverse relationship between CCF and ROSC that varied depending upon the time from arrest to provision of EMS-CPR.

Introduction

The 2015 international guidelines for adult basic life support (BLS) recommend a compression rate of 100–120 compressions per minute (cpm) and a chest compression depth of 50–60 mm during cardiopulmonary resuscitation (CPR) [1,2]. Both compression rate and depth have been linked to patient survival outcomes [3]. For chest compression fraction (CCF) however, although guidelines [1,2] state that rescuers should maximise the CCF delivered, its relationship with survival has not been as clear. Whilst a 2009 paper [4] found that increased CCF was independently predictive of better survival in out-of-hospital cardiac arrest (OHCA) patients with a shockable initial rhythm, a number of recent studies have reported an inverse association between CCF and return of spontaneous circulation (ROSC), survival to hospital discharge (STHD) and neurologically intact survival in OHCA [5,6]. Several hypotheses have been proposed to attempt to explain this seemingly counter-intuitive observation. Wik et al. reported that there was an inverse relationship between CCF and survival, but after statistical adjustment for possible confounders, the relationship was in the expected direction [7]. Another study [5] however found that the relationship remained inverse despite adjustment for so-called Utstein predictors [8,9] and for several CPR quality metrics. The authors proposed

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that the relationship between CCF and survival outcomes may be time-dependent. Rea et al. also noted that the relationship between CCF and ROSC, survival to hospital discharge (STHD) and survival with favourable neurological outcome was linked to the duration of CPR delivered by emergency medical services (EMS) [10].

Animal studies [11–14] have similarly shown time-dependency; the deliberate introduction of breaks in compressions during the initial minutes of CPR was associated with survival benefit for cases where resuscitation efforts had been delayed by 15–17 min from onset of arrest. Referred to as 'post conditioning' (PC), the proposed mechanism is that, following an extended period with no circulation, the deliberate introduction of pauses during CPR may help to prevent reperfusion injury in the myocardium and brain [15,16]. Collectively, there is a growing body of evidence suggesting the potentially time-dependent nature of the relationship between CCF and survival. We therefore sought to investigate this relationship further and determine whether it varied depending on the time between onset of arrest and delivery of EMS-CPR.

Methods

Study design

We conducted a retrospective observational study of OHCA cases that had had resuscitation attempted by St. John Ambulance Western Australia (SJA-WA) paramedics in the Perth metropolitan area between July 2014–June 2016. We considered arrests of all causes in patients aged eight years or older. Specifically we sought cases that had a record of CPR quality and we explored its relationship with survival outcomes.

Setting

SJA-WA is the sole provider of road EMS in the state of Western Australia (WA). The capital city, Perth, has a population of approximately 2.0 million within a land area encompassing 6418 square kilometres [17].Information about all EMS-attended cardiac arrests is captured within the OHCA database that is maintained at the Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU) at Curtin University on behalf of SJA-WA. The database contains information sourced from the SJA-WA paramedic-completed electronic patient care records (ePCRs) supplemented with patient outcome data from in-patient hospital records and the WA Death Registry.

CPR quality data

We identified cases that had CPR quality data captured using the Q-CPR™ feedback device [18]. We only included cases with at least one minute of CPR quality data. The Q-CPR device is meant to be used by SJA-WA paramedics during all attempted resuscitations of patients aged 8 years and above where a mechanical compression device is not in use. The Q-CPR collects data on compression rate, depth, fraction, chest recoil, duty cycle and ventilation rate. For each case we imported individual Microsoft Excel files containing 30 s summary data for each CPR quality metric. We utilised a bespoke algorithm to find the mean for each metric over the measurement interval. We excluded from calculations any periods of ROSC documented in the ePCR. To increase the integrity of our data, we also manually reviewed apparent breaks in compressions of greater than 30 s to determine, by comparison against electrocardiography (ECG) data, whether these were true breaks in compressions or a break in the use of Q-CPR. We likewise excluded the end of the recorded data interval if the data was contaminated by artefact from moving or unplugging the Q-CPR device.

Relationship between CPR quality and outcome

We used multivariable logistic regression analysis with robust estimates of variance to investigate the relationship between CPR quality metrics and survival outcomes. The survival outcomes examined were: ROSC present at any time during the resuscitation, STHD and good neurological outcome at hospital discharge. The patient's neurological status was determined by medical chart review; a cerebral performance category (CPC) score [19] of 1 or 2 was defined as 'good' neurological outcome. We assessed whether having compression rate, depth and CCF in compliance with current ERC and/or AHA guidelines was associated with improved patient outcomes. Although current AHA and ERC guidelines [1,2] recommend a CCF above 60%, the AHA expert consensus is that a CCF of 80% is achievable in a variety of settings [1]. Therefore we considered a CCF cut-off of 80% in our regression models. We calculated unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) and then adjusted for compression rate, depth and CCF and the Utstein predictors of survival [8,9]. We used all available data within the resuscitation episode for this analysis.

Time-dependent relationship between CCF and survival outcomes

We investigated whether the relationship between CCF and survival outcomes varied depending upon the time from onset of arrest to the provision of EMS-CPR ('downtime'). Specifically we defined downtime as the interval between time of arrest (as estimated from bystanders' and paramedics' descriptions in the ePCR) and the recorded EMS arrival time on scene. We used the time of EMS arrival because in the majority of cases the time from EMS arrival to commencement of CPR was very short unless otherwise documented in the ePCR. Because estimation of downtime was done retrospectively, to minimise potential error we used a conservative approach recording the maximum reasonable downtime based upon descriptions, and where it was not possible to estimate, we coded the downtime variable as "unknown" and analysed it separately. We also used the first recording of patient temperature to justify our estimates. We considered that the downtime was longer than 15 min if the first recording of body temperature was below 35 °C but did not assume the inverse [20]. This retrospective estimation of downtime was conducted by two authors (MT and HT). Consensus was sought in case of disagreement between the two. We divided cases into downtime ≤15 min versus >15 min based upon the definition of 'prolonged' downtime used within the majority of animal studies [11–13].

We compared the mean (SD) CCF for cases with and without ROSC within each of the two downtime categories and for the unknown cases. CCF was calculated using recordings from the first three minutes of CPR only because in animal studies 'post conditioning' was administered during the first three minutes. We subsequently computed unadjusted and adjusted OR for achieving ROSC with CCF > 80% compared to CCF ≤ 80% for cases with downtime ≤15 min, downtime >15 min and for cases with an unknown downtime. We adjusted for age and two key predictors of survival: bystander CPR and shockable initial rhythm [8]. We also adjusted for compression depth and compression rate.

Statistical analysis

We conducted univariate analysis using *t*-tests or Mann-Whitney *U* tests for comparison of continuous variables and chi-squared tests or Fisher's exact tests for categorical variables, assessed at the 5% level of significance. We used IBM SPSS version 22.0 (IBM, Armonk, NY) for decision tree and neural network anal-

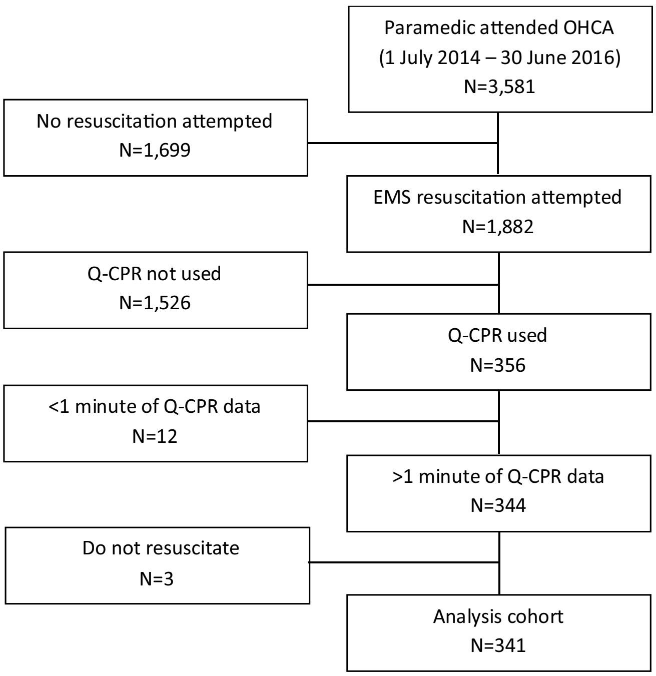

Fig. 1. Patient flow diagram of analysed cohort and exclusions.

Table 1
Baseline characteristics of analysed cohort (July 2014–June 2016).

Characteristic	Analysed cohort[a] (n = 341)
Age, mean (SD)	62.21 (20.19)
Male (%)	69.79
Witnessed arrest (%)	
EMS witnessed	4.99
Bystander witnessed	29.32
Unwitnessed	65.69
Bystander CPR (%)	60.12
Arrest location (%)	
Public	13.49
Residential	79.47
Other	7.04
Presenting initial rhythm (%)	
VF/VT	20.23
PEA	20.23
Asystole	59.53
Medical cause of arrest (%)	83.87
Response time (minutes), mean (SD)[b]	8.04 (6.94)
ROSC (Any), n (%)	85 (24.93)
STHD, n (%)	12 (3.52)
Good neurological outcome at hospital discharge, n (%)	10 (2.93)

EMS: emergency medical service; ROSC: return of spontaneous circulation; STHD: survival to hospital discharge; VF: ventricular fibrillation; VT: ventricular tachycardia.

[a] OHCA cases that had resuscitation attempted by paramedics, had at least 1 min of CPR quality data recorded using the Q-CPR device and did not have a 'do not resuscitate' (DNR) advance directive.

[b] Time interval from emergency call to the arrival of the first EMS vehicle on scene.

yses (see below) and StataSE13.1 for all other analyses (StataCorp LP, College Station, TX).

Sensitivity analyses

We conducted three sensitivity analyses to further explore the relationship between CCF and ROSC. Firstly, we repeated initial logistic regression analyses using three different durations (3, 5 and 10 min) of CPR quality measurement to investigate whether the duration affected our results. In our previous paper we described

Table 2
Odds ratios for survival outcomes by compliance of compression depth, rate and fraction with AHA and ERC guidelines; calculated using all available episode data.

Compliance of CPR quality metrics with ERC/AHA guidelines	Number compliant (n)	ROSC (Any)		STHD		Good neurological outcome at hospital discharge	
		Unadjusted OR (95% CI)	Adjusted[a] OR (95% CI)	Unadjusted OR (95% CI)	Adjusted[a] OR (95% CI)	Unadjusted OR (95% CI)	Adjusted[a] OR (95% CI)
Depth 50–60 mm, Rate 100–120cpm and Fraction >80%	15	1.10 (0.34, 3.55)	1.09 (0.36, 3.26)	[b]	[b]	[b]	[b]
Depth 50–60 mm	54	0.84 (0.42, 1.68)	0.74 (0.35, 1.55)	1.82 (0.48, 6.94)	1.22 (0.36, 4.17)	1.34 (0.28, 6.50)	1.02 (0.27, 3.85)
Rate 100–120cpm	216	0.88 (0.53, 1.47)	0.85 (0.50, 1.46)	0.80 (0.25, 2.59)	0.65 (0.17, 2.57)	0.86 (0.24, 3.12)	0.83 (0.20, 3.38)
Fraction >80%	154	0.47 (0.28, 0.79)	0.49 (0.28, 0.87)	0.39 (0.10, 1.48)	0.61 (0.17, 2.24)	0.51 (0.13, 2.01)	0.86 (0.20, 3.68)

AHA: American Heart Association; CI: confidence interval; CPR: cardiopulmonary resuscitation; ERC: European Resuscitation Council; OR: odds ratio; ROSC: return of spontaneous circulation; STHD: survival to hospital discharge.

[a] Adjusted for Utstein characteristics and compression depth, rate and fraction as required.

[b] There were no survivors in the group with mean compression depth, rate and fraction within the ranges recommended by AHA/ERC guidelines.

the high degree of heterogeneity within the published literature in the length of data interval used when investigating the link between CPR quality and survival outcomes [21]. Secondly, we sought to investigate whether adjusting for the same variables as Wik et al. [7] changed the direction of the relationship observed between CCF and ROSC in our cohort; we derived logistic regression models examining CCF as a continuous variable while adjusting for the same factors as Wik et al. with the exception of site location (not applicable to our study) and median duration of treatment [7]. Thirdly, we derived a classification tree with Classification and Regression Tree (CART) modelling and likewise employed artificial neural network (ANN) analysis to examine whether the inverse relationship between CCF and survival outcomes was consistent regardless of the method of statistical modelling used. A decision tree is a flowchart-like model that illustrates the key factors predictive of outcome and their corresponding cut-off points. ANN is used for complex pattern-recognition tasks and likewise reports the key factors predictive of outcome. These techniques have been applied previously in prehospital [22] and cardiac research [23]. In our study we compared results derived using these two methodologies to those from logistic regression, while also comparing the degree of predictability of the models through comparison of the respective areas under the receiver operating characteristic (AUROC) curves.

Ethics approval

Ethics approval for this study was granted by the Human Research Ethics Committee of Curtin University (HR128/2013).

Results

There were 3581 OHCAs that occurred in Perth during the study period. Over half of the cases (1882) had resuscitation attempted by paramedics. Q-CPR was utilised in 356 cases. Twelve cases were excluded due to there being less than one minute of Q-CPR data recorded. A further three cases were excluded due to resuscitation being started but subsequently terminated when the cases were discovered to have a ‘do not resuscitate’ advance directive in place. This resulted in 341 cases being included in the analysed cohort (Fig. 1). The Utstein characteristics and survival rates for this cohort are described in Table 1.

Relationship between CPR quality and outcome

There was no significant association with ROSC (aOR: 1.09, 95%CI: 0.36–3.26) when all three metrics (compression depth, rate and CCF) met ERC and AHA guidelines (Table 2). There were only 15 patients in this group and none of them survived to hospital discharge. Compression depth and rate were not significantly associated with any survival outcomes (Table 2). However, CCF was significantly associated with ROSC (Table 2); a CCF of >80% was associated with decreased odds of ROSC (aOR: 0.49, 95%CI: 0.28-0.87). The relationship was not significant for STHD nor for the outcome of good neurological outcome at hospital discharge (Table 2).

Time-dependent relationship between CCF and survival outcomes

For arrests with a downtime of ≤15 min, there was no significant difference in CCF between those who did and did not achieve ROSC (mean (SD): 75.59 (12.14)% vs. 76.69 (11.35)%; p = 0.69) (Table 3), nor for those who did and did not STHD (mean (SD): 76.55 (14.59)% vs. 76.23 (11.44)% p = 0.58). However, among those with a downtime >15 min, those with ROSC had a significantly lower CCF compared to those without (mean (SD): 73.01 (12.99)% vs. 83.05 (9.38)% p = 0.002) (Table 3). Among cases with an unknown downtime, there was no significant difference in CCF between those with and without ROSC (mean (SD): 80.75 (8.09)% vs. 80.32 (12.72)%; p = 0.96) (Table 3). We likewise found no significant differences in other CPR quality metrics and Utstein variables between those with and without ROSC in each of the three downtime categories (Table 3).

Among patients with downtime >15 min, the odds of those with CCF > 80% achieving ROSC were 93% lower than for those with CCF ≤ 80% (OR: 0.07, 95% CI: 0.01–0.33) (Table 4). After adjusting for age, bystander CPR, shockable initial rhythm, compression depth and compression rate, the odds remained significant (aOR: 0.06, 95%CI: 0.01–0.38) (Table 4). In the group with a downtime ≤15 min, the odds of ROSC were not significantly different with a CCF > 80% compared to ≤80% (aOR: 0.63, 95%CI: 0.23–1.71) (Table 4). Other CPR quality metrics were not significant predictors of ROSC.

Sensitivity analyses

We found that higher CCF was significantly associated with lower odds of ROSC when using the 3 and 5 min dataset, but not significant when using the 10 min dataset (aOR: 0.64, 95%CI: 0.35–1.15). We found that in a logistic regression model adjusting for the same variables as Wik et al. [7] CCF remained significantly and inversely associated with ROSC (aOR for ROSC: 0.96 (95%CI: 0.93, 0.98)). Using ANN we found that CCF was a key predictor of ROSC (Appendix A of Supplementary material). Using CART we found that lower CCF was always associated with a higher rate of ROSC in our derived decision tree (Appendix A of Supplementary material). We also found that CCF was not a predictor for ROSC if response time was less than or equal to 4.3 min (Appendix A of Supplementary material). The predictabilities (as represented by AUROC) of these two methodologies were similar to that of logistic regression analysis (0.69 (95%CI: 0.62–0.75) for the logistic regression model vs. 0.72 (95%CI: 0.66–0.78) for the decision tree and 0.687 (95% CI: 0.685–0.689) for ANN).

Discussion

Our results show that CCF was inversely and significantly associated with ROSC. This was true across three of the four time durations examined; the first 3 and 5 min of EMS-CPR and all available episode data. Furthermore, the relationship between CCF and ROSC appeared to vary depending on the timing from onset of arrest to provision of EMS-CPR.

Our results are consistent with other recently published studies that show that a higher CCF was associated with lower odds of ROSC [5,6]. These studies used all available episode data in their analyses. Their approach differed to earlier work by Christenson et al. [4] that utilised data only until the first analysis check, a mean (IQR) of 1.6 (1.1) minutes [5], to demonstrate a positive relationship between CCF and survival. In our present work we demonstrated an inverse relationship both during the initial minutes of resuscitation as well as across all available episode data. We also compared our findings to those of Wik et al. [7] who reported that the relationship between CCF and survival changed from inverse to positive following adjustment for variables associated with CCF and/or survival. We adjusted for the same predictors as Wik et al. (with the exception of median duration of treatment) however found that the relationship remained inverse. We also utilised alternative methods of analysis to test our findings. Using decision tree analysis we found that depending on EMS response time a lower CCF was associated with higher rates of ROSC.

Other authors have proposed that the relationship between CCF and survival outcome is time-dependent [5,10]. We sought

Table 3
Univariate comparison of Utstein OHCA characteristics and CPR quality metrics between cases with and without ROSC (Any), grouped by downtime from onset of arrest to EMS arrival on scene, calculated using data from the first 3 min of CPR.

Characteristic	Downtime ≤ 15 minutes			Downtime > 15 minutes			Unknown downtime		
	ROSC	No ROSC	P − value	ROSC	No ROSC	P − value	ROSC	No ROSC	P − value
N	30	45		15	83		9	20	
Age (years)	65.77 (17.70)	64.09 (17.71)	0.69	53.73 (24.71)	60.81 (19.83)	0.28[b]	52.22 (20.60)	60.65 (22.16)	0.35[b]
Male (%)	76.67	77.78	0.91	53.33	71.08	0.17	77.78	75.00	1.00[a]
Bystander-witnessed arrest (%)	46.67	53.33	0.57	13.33	15.66	1.00[a]	0	0	N/A
Paramedic-witnessed arrest(%)	6.67	11.11	0.70[a]	0	0	N/A	0	0	N/A
Bystander-CPR (%)	60.00	60.00	1.00	46.67	69.88	0.08	88.89	50.00	0.10[a]
Public location of arrest (%)	23.33	20.00	0.73	13.33	6.02	0.29[a]	22.22	20.00	1.00[a]
Shockable initial rhythm (%)	43.33	24.44	0.09	6.67	9.64	1.00[a]	0	10.00	1.00[a]
Medical cause of arrest (%)[c]	86.67	93.33	0.43[a]	73.33	79.52	0.73	88.89	80.00	1.00[a]
Response time (min)[d]	5.91 (2.01)	6.87 (2.88)	0.12	6.73 (3.08)	8.50 (4.01)	0.17[b]	8.16 (5.12)	5.57 (2.26)	0.09[b]
Compression depth (mm)	41.82 (7.99)	39.32 (8.91)	0.22	41.50 (9.26)	42.53 (9.15)	0.65[b]	40.69 (12.26)	43.80 (10.83)	0.45[b]
Compression rate (cpm)	113.81 (15.77)	115.91 (15.28)	0.57	116.25 (14.77)	114.69 (13.64)	0.76[b]	115.89 (14.95)	116.38 (14.95)	0.85[b]
Compression fraction (%)	75.59 (12.14)	76.69 (11.35)	0.69	73.01 (12.99)	83.05 (9.38)	0.002[b]	80.75 (8.09)	80.32 (12.72)	0.96[b]
Duty cycle (%)	42.33 (4.69)	42.50 (4.11)	0.86	43.54 (3.43)	42.89 (3.09)	0.31[b]	41.01 (3.74)	43.50 (2.54)	0.06[b]
Leaning (%)	15.69 (21.86)	16.52 (25.80)	0.88	12.89 (18.27)	13.92 (20.20)	0.89[b]	8.55 (13.23)	9.27 (11.15)	0.74[b]
Ventilation rate (vpm)	4.00 (4.81)	2.68 (2.96)	0.14	2.53 (2.08)	2.27 (2.71)	0.39[b]	3.08 (2.42)	2.88 (2.61)	0.74[b]

EMS: emergency medical service; ROSC: return of spontaneous circulation.
Results listed as mean (SD) or percentage as relevant.
[a] P-value calculated using non-parametric methods (Fisher's Exact Test).
[b] P-value calculated using non-parametric methods (Mann-Whitney U Test).
[c] Previously referred to as 'presumed cardiac cause'.
[d] Time interval from emergency call to the arrival of the first EMS vehicle on scene.

Table 4
Odds of ROSC (Any) for CCF >80% compared to CCF ≤ 80%, categorised by downtime from onset of arrest to arrival of the first EMS on scene; calculated using data from the first 3 min of CPR.

Downtime	N	Unadjusted OR	95%CI	Adjusted[a] OR	95%CI	Adjusted[b] OR	95%CI
≤15 min	75	0.63	(0.24, 1.63)	0.61	(0.23, 1.63)	0.63	(0.23, 1.71)
>15 min	98	0.07	(0.01, 0.33)	0.07	(0.01, 0.38)	0.06	(0.01, 0.38)
Unknown	29	1.63	(0.32, 8.45)	1.33	(0.15, 11.82)	1.26	(0.15, 10.75)

CCF: chest compression fraction; CI: confidence interval; EMS: emergency medical service; OR: odds ratio; ROSC: return of spontaneous circulation.
[a] Adjusted for patient age, shockable rhythm and bystander CPR.
[b] Adjusted for patient age, shockable rhythm, bystander CPR, compression depth and compression rate.

to investigate whether it varied depending upon downtime from onset of arrest to delivery of EMS-CPR, prompted by positive findings from animal studies [11–13]. We found that for arrests with a 'prolonged' downtime of greater than 15 min, a higher CCF during the first 3 min of CPR was significantly associated with lower odds of ROSC. This was not the case with downtime ≤15 min or for the cases with unknown downtime. This finding suggests that there may be survival advantages associated with the deliberate introduction of breaks in compressions during the first minutes of CPR where patients have been without circulation for an extended period. While in animal models the use of PC, either alone [13] or bundled with other therapies [11,12], was linked to increased survival, we could not demonstrate this in our dataset. The downtime used in animal studies was 15–17 min, however our cohort contained many cases with a substantially longer downtime, up to several hours. Neurological recovery may be less likely despite the use of PC in such cases. We had too few survivors to conduct logistic regression analyses in each of the downtime groups. However, given that ROSC is a necessary precursor for survival [8], the fact that we observed an association between CCF and ROSC provides an optimistic outlook for an association with survival in those patients with a downtime marginally, but not substantially, greater than, 15 min. We therefore recommend that a retrospective analysis similar to the one described herein be conducted by others using a larger dataset. Our preliminary results also provide reason for further investigation into whether a single CCF recommendation is appropriate for all patients.

Limitations

Our analysed cohort represented less than one fifth (18.1%) of all OHCA cases with resuscitation attempted. However, we found that cases with Q-CPR data did not differ significantly on Utstein characteristics compared to all cases with resuscitation attempted (Appendix B of Supplementary material) with the exception of significantly lower proportions of paramedic-witnessed arrests ($p < 0.001$) and arrests occurring in a public location ($p = 0.04$) in our study cohort. These differences may help to explain why STHD was significantly lower in our cohort (3.5% vs 11.6%; $p < 0.001$) but also may signify a higher proportion of patients with a prolonged downtime thus allowing us to more easily identify an inverse relationship between CCF and ROSC in our cohort.

We encountered difficulty with recruitment due to low usage rates of the Q-CPR device; the reasons for this were outlined in our previous paper [24]. Given the sample size available, we may have lacked the power to detect a significant difference in some variables using univariate analysis and to perform meaningful regression analyses in some instances where the distribution of patients was highly polarised. Nevertheless, we had sufficient power to demonstrate a significant relationship between CCF and ROSC, including in the group with downtime >15 min.

Conclusions

We demonstrated an inverse relationship between CCF and ROSC, regardless of whether we analysed data from the first few minutes of CPR or all available episode data. Furthermore, a lower

CCF during the initial minutes of CPR appeared to be more important in cases with a prolonged downtime of greater than 15 min. Further research is required to understand the growing evidence for this counter-intuitive finding.

Grant

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Potential conflict of interest

Prof. Judith Finn is the Director of the Australian Resuscitation Outcomes Consortium (Aus-ROC), a NHMRC Centre of Research Excellence (CRE #1029983), and receives partial salary support from St John Ambulance Western Australia (SJA-WA). A/Prof. Paul Bailey is Clinical Services Director at SJA-WA. Mr. Deon Brink is the Executive Manager Clinical Governance at SJA-WA. Dr. Madoka Inoue maintains the SJA-WA OHCA database and receives partial salary support from SJA-WA and Aus-ROC. Ms. Milena Talikowska is a PhD student funded by Aus-ROC. There are no other potential conflicts of interest to declare. The authors alone are responsible for the content and writing of the paper.

Author contribution

MT, HT and JF were involved in the conception and design of the study. Data was sourced from St. John Ambulance Western Australia (SJA-WA) in consultation with DB and PB. The study dataset was extracted from the SJA-WA OHCA database with the important assistance of MI, the database manager. MT and HT conducted all data cleaning and analysis. MT and HT prepared the manuscript; all other authors were involved in the revision of the article critically for important intellectual content, and final approval of the version to be submitted.

All have given approval to submit this article.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2017.05.005.

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