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Clinical paper

Effectiveness of team-focused CPR on in-hospital CPR quality and outcomes

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Abstract

Objective: We sought to identify changes in neurological outcome over time following initial training and subsequent implementation of team-focused CPR in an inpatient setting where responders practice specific roles with emphasis on minimally interrupted chest compressions and early defibrillation.

Methods: This retrospective pre- vs post-intervention study was conducted at an urban 900-bed teaching hospital and Level I Cardiac Resuscitation Center. We included adult patients suffering in-hospital cardiac arrest occurring in non-emergency department and non-intensive care unit areas who received CPR and/or defibrillation. We compared survival with good neurological outcome at time of hospital discharge in the one-year periods before and after implementation of team-focused CPR. To investigate skill degradation, we compared cumulative survival with good neurological outcome in 3-month intervals against the before team-focused CPR baseline. Trained research associates abstracted explicitly defined variables from electronic health records using a standardized form and data dictionary to achieve consistency between collaborators.

Results: Of 296 IHCAs, 207 patients met inclusion criteria and were analyzed. In 104 patients before team-focused CPR initiation, survival with good neurological outcome was 21%. In the 12-month period following team-focused CPR initiation, survival with good neurological outcome was 31% in 101 patients, risk difference 9.9% (95% CI −2 to 22%; p = 0.14). By quarterly time intervals, following team-focused CPR implementation, the cumulative survival with good neurological outcome at 3 months was 42%; at 6 months 37%; at 9 months 31%; and at 12 months 31%.

Conclusion: In our single-institution implementation of team-focused CPR for in-hospital cardiac arrest, outcomes significantly improved at 6 months before declining towards baseline.

Keywords: CPR, Cardiac arrest, Team learning, Education

Introduction

Over 290,000 patients experience an in-hospital cardiac arrest each year in the United States.[1] Advances in cardiac arrest resuscitation have led to a steady increase in survival to hospital discharge after in-hospital cardiac arrest (IHCA) from 2000 to 2017, but even with this uptrend, the average survival to hospital discharge amongst large cardiac arrest studies was only 20%.[1]

A 2023 initiative by the International Liaison Committee on Resuscitation (ILCOR) aims to combat the historically suboptimal quality of care and outcomes related to IHCA. In summary, the ILCOR's Ten Steps Toward Improving IHCA fall under four categories: Plan and Prepare, Prevent, Principles and Culture, and Perform.[16] Our study focuses mostly on the Plan and Prepare aspect of the ILCOR's Ten Steps, aiming to mitigate variation in cardiac arrest care and outcomes. Vetted by the American Heart Association and various other notable worldwide organizations, the ILCOR's recommendations certify the value in implementing effective education and training- a joint value in both the Ten Steps and team-focused CPR alike. The ability to not only implement training but collect data and eventually improve outcomes is another shared goal that validates the relevance of supporting team-based programs in the realm of resuscitation.[16,17]

Effective team-based cardiopulmonary resuscitation (CPR) is a complex process that involves a high-functioning team to execute

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optimal resuscitative performance. The importance of rapid, seamless transitions between the different components of CPR is essential, as is the team leader coaching, for optimal performance[2]. Additionally, effective team dynamics are essential given diversity among provider disciplines, experiences, and skill sets.[3] When teams of healthcare providers are well-rehearsed in each crucial aspect of CPR, resuscitations can be delivered more effectively.

Advancements in team-based resuscitation in the out-of-hospital cardiac arrest (OHCA) setting have led to the exploration of whether certain OHCA interventions could improve IHCA resuscitation outcomes. One such resuscitation strategy is known as Team Focused Cardiopulmonary Resuscitation, also known as "pit crew" CPR, which is a choreographed approach to CPR where teammates know and practice their role in resuscitation, with prioritization on minimally-interrupted chest compressions and early defibrillation. The initial proposal of pit crew resuscitation by Hopkins et al describes not only a choreographed approach with team members aware of their individual duties beforehand, but "task completion in parallel with virtual autonomy," much like the Formula One teams; each member racing around the car to complete a task proficiently and independently but with the same common goal.[18] One study in North Carolina showed this team-based method improved neurological outcomes, defined as a Pittsburgh Cerebral Performance Category (CPC) of 1–2 at time of hospital discharge, when compared to traditional CPR (8.4% vs 4.8%) in a cohort of 14,994 OHCA patients.[4] Whether this team-focused CPR, pre-hospital approach could offer the same benefit with IHCA has not yet been investigated.

Optimal retraining timing is an area of evolving discovery [19,20,21]. Some studies suggest monthly retraining, citing short, spaced repetition as the major contributor for maintaining CPR skills that follow depth, rate, and recoil standards.[5] Other research recommends continued training until mastery of compression technique is acquired; retraining intervals are then individualized based on provider competency, rather.[6] Skill degradation is a recognizable and measurable data point that our research aims to address.

The primary objective of this retrospective before-and-after observational cohort study is to assess the impact of team-focused CPR on good neurological outcome at time of hospital discharge in IHCA patients. Secondary outcomes include return of spontaneous circulation (ROSC), survival to hospital discharge, and assessing differences in outcomes over time and how this relates to degradation in compression proficiency.

Methods

Study design and setting

All patients were enrolled from Carolinas Medical Center, an urban, 900-bed teaching hospital. Carolinas Medical Center is a receiving hospital for patients experiencing cardiac arrest with a network of 25 transferring hospitals in the region, as well as an ST-elevation myocardial infarction (STEMI) treating hospital as designated by the American Heart Association Mission: Lifeline® Regional Systems of Care Program. At Carolinas Medical Center, we anticipate 120 non-intensive care unit (ICU), non-emergency department (ED) cardiac arrests per year. This study and its methods were approved by the Institutional Review and Privacy Board at Carolinas Medical Center for research in the ED (IRB#05–16-12E); A waiver of informed consent was issued by the Institutional Review Board for the retrospective chart review and data analysis, given that patients will not be contacted and that the research presents no more than minimal risk of harm to the subjects.

Clinical staff that participate in resuscitations were trained in mandatory simulation sessions held in hospital conference areas and in simulation labs. Resident physicians from the Departments of Emergency Medicine, Internal Medicine, and Family Medicine were required to undergo training as these residents represent those that respond to in-hospital arrests as part of the Code Blue rapid response team. Additionally, all interns entering the hospital system in 2016 were introduced to team-focused CPR training during their structured multi-disciplinary onboarding training. Nurses, technicians, and respiratory therapists also underwent structured training prior to the implementation of team-focused CPR. Any new staff members hired after the initial training sessions were expected to be onboarded to the process prior to initiation of patient care. This team-focused CPR training period occurred over a 1-year interval prior to in-hospital deployment and included multi-model strategies of in-person lectures, asynchronous education materials, and team-based simulation training sessions. Medical personnel were trained on the specific roles and locations of responders during a Code Blue and multiple rounds of mock resuscitation were performed until all participants had a full understanding of how to appropriately function at each potential position. The team-focused CPR training details a resuscitation with sequential cycles of 200 chest compressions with the performing clinician reporting their progress aloud after each twentieth compression at which time a ventilated breath will also be given. The defibrillator is charged at the 180th compression with a team member keeping contact with the femoral pulse from this point until compressions are stopped at the 200th compression for a rhythm and pulse check. If no shock is indicated, begin the next round of 200 compressions. When appropriate, a shock is delivered and the next cycle of chest compressions is immediately resumed. Compression efficacy is guided throughout resuscitation by both code leader input and audiovisual CPR feedback tools. This sequence in addition to distinct training on how and when to perform interventions was repeated until all parties felt comfortable integrating this protocol into practice.

The specific roles of each provider in team-focused CPR have been previously well-described in a 2017 study by Johnson et al.[7] This study described the team-focused CPR adaptation from pre-hospital teams to a systemic approach used by providers in the emergency department (ED) with focus on early defibrillation and high-quality chest compressions with minimal interruptions in compressions and utilizing multiple compressors to decrease fatigue of any individual compressor.[7] The study additional highlighted regularly used interventions that often hinder optimal compression delivery such as vascular access attempts, advanced airway placement, and administration of intra-arrest medications and how initiation of team-focused CPR can streamline these interventions during resuscitation. The authors detail how the team-focused CPR process can mitigate delays during resuscitation such as utilizing intraosseous access if intravenous access is not made immediately and a bag valve mask or blind insertion airway device is preferred over endotracheal intubation.

At our institution, in-hospital team-focused CPR performed outside the ED does have some variations when compared with the ED team layout demonstrated by Johnson et al.[7] This layout can be seen in Fig. 1 which further details the in-hospital modification of ED team-focused CPR.

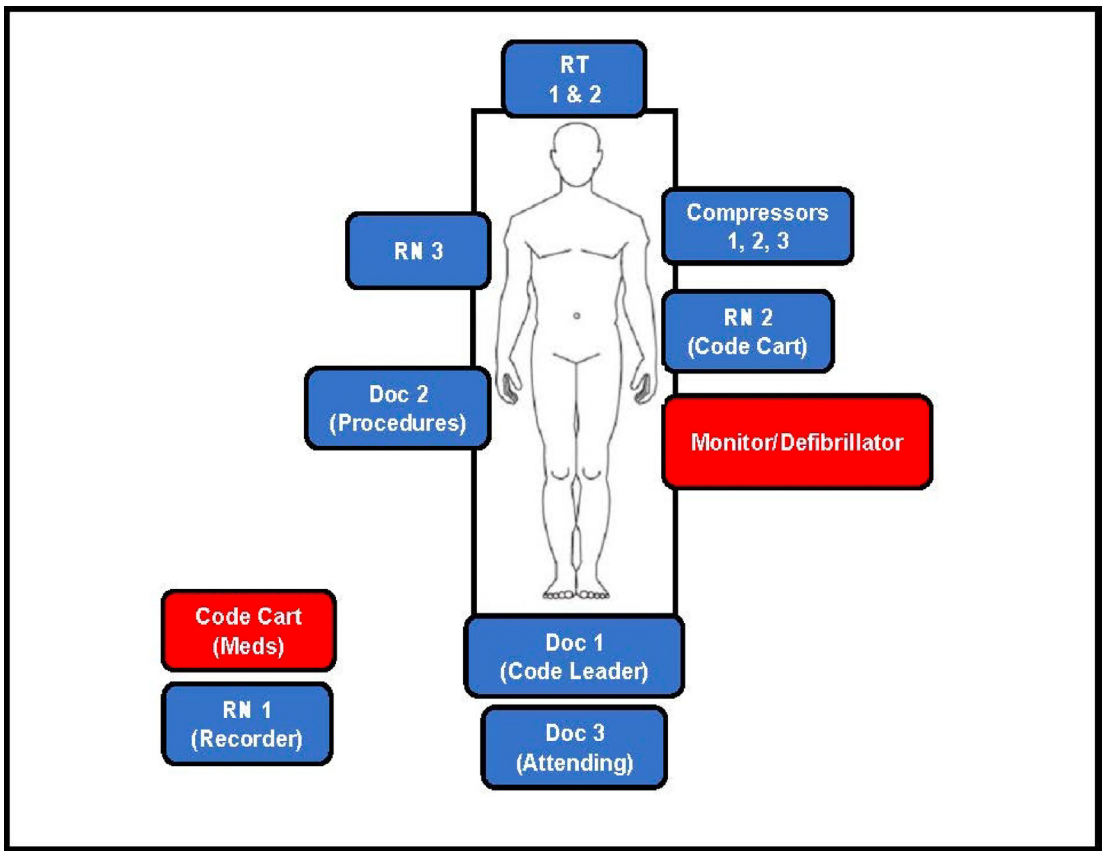

Fig. 1 – Proposed TFCPR schematic for provider positioning during Code Blue activation at a large urban academic medical center. RT = respiratory therapist; RN = registered nurse; Doc = MD/DO. RT 1 & 2 = respiratory therapists manage the airway, ensure 1 breath per 20 compressions. Compressors 1, 2, & 3 = count aloud every 20 compressions, utilize a CPR feedback device and switch off after 200 compressions: often post-graduate year, PGY-1 residents or medical students. RN 1 = the nurse recorder, will pull code cart meds and time all resuscitation efforts on the code sheet. RN 2 = the code cart nurse; attach the monitor, charge defibrillator at compression 180 of 200, and administer shock after compression 200 of 200 as prompted by the code leader. RN 3 = nurse ensuring IV/IO access, obtain blood for point-of-care labs, and administer medications. Doc 1 = code leader, typically the upper-level resident (post-graduate year, PGY-2 or 3) first on scene when a Code Blue is activated; guide all aspects of resuscitation, ensure high-quality CPR with minimal interruptions, and perform rhythm analysis at pulse checks. Doc 2 = in charge of procedures such as point-of-care ultrasound, assisting with airway or line placement, and pulse checks. Doc 3 = attending physician overseeing performance of all team members, responsible for keeping the room quiet and controlled; typically, a medical critical care attending at our institution.

Patient inclusion and exclusion criteria

Consecutive patients who arrested in-hospital outside of the ICU or ED were identified via Code Blue form completion per hospital protocol and screened for study inclusion. Inclusion criteria were medical cardiac arrest resuscitations that involved patients aged 18 and older. Exclusion criteria included cardiac arrest secondary to trauma, out-of-hospital cardiac arrest, patients aged less than 18, and patients with Do Not Resuscitate/Do Not Intubate status. All patients that had a Code Blue paper form completed per standard hospital protocol was reviewed for eligibility during the study period.

Data analysis

A retrospective chart review was done on all adult, medical cardiac arrest patients treated in Carolinas Medical Center inpatient units that met inclusion and exclusion criteria during the one-year pre-team-focused CPR period (August 1, 2015 to July 31, 2016) and the one-year post-team-focused CPR period (August 1, 2016 to July 31, 2017). This review excluded cardiac arrests that occurred in the ED or in the ICU. The pre- and post-intervention data outlined in Table 1 details patient characteristics like age, race, gender, ethnicity, and known comorbidities. Other variables captured both before and after intervention include arrest and treatment variables such as location of index arrest, whether or not the arrest was witnessed, initial rhythm, and etiology of arrest, detailed in Table 2. Endpoints evaluating ROSC, survival to hospital discharge, and survival with good neurological outcome were also captured as seen in Table 3. This data was collected on consecutive patients with the use of a preformatted standard data collection tool utilizing similar elements of Utstein criteria which is traditionally used to capture out-of-hospital cardiac arrest data. Data capture was performed utilizing standard forms within the REDCap database; explicitly defined variables were abstracted from electronic health records by trained

Table 1 – Patient characteristics.

	Pre-team-focused CPR (%) (n = 104)	Post-team-focused CPR (%) (n = 103)	Q1 (n = 24)	Q2 (n = 33)	Q3 (n = 29)	Q4 (n = 17)
Age – mean years (SD)	65.5 (14.1)	62.6 (17.2)	68.1 (14.9)	60.6 (16.5)	64.3 (20.0)	56.0 (14.7)
Male	74 (71)	59 (57)*	11 (45.8)	20 (60.6)	18 (62.1)	10 (58.8)
Race						
White	49 (47)	53 (52)	13 (54.2)	17 (51.5)	15 (51.7)	8 (47.1)
Black or African American	47 (45)	40 (39)	9 (37.5)	12 (36.4)	12 (41.4)	7 (41.2)
American Indian/Alaskan	0 (0)	3 (3)	0 (0)	1 (3.0)	1 (3.4)	1 (5.9)
Asian	1 (1)	1 (1)	1 (4.2)	0 (0.0)	0 (0.0)	0 (0.0)
Other	4 (4)	4 (4)	0 (0)	3 (9.1)	0 (0.0)	1 (5.9)
Unknown	3 (3)	2 (2)	1 (4.2)	0 (0.0)	1 (3.4)	0 (0.0)
Ethnicity						
Non-Hispanic	97 (93)	94 (91)	24 (100)	30 (90.9)	25 (86.2)	15 (88.2)
Hispanic	2 (2)	4 (4)	0 (0)	2 (6.1)	1 (3.4)	1 (5.9)
Unknown	5 (5)	5 (5)	0 (0)	1 (3.0)	3 (10.3)	1 (5.9)
Comorbidities						
Chronic heart failure	17 (16)	27 (26)	6 (25)	7 (21.2)	11 (37.9)	3 (17.6)
Previous MI	7 (7)	10 (10)	1 (4.2)	3 (9.1)	5 (17.2)	1 (5.9)
Coronary artery disease	25 (24)	28 (27)	5 (20.8)	9 (27.3)	11 (37.9)	3 (17.6)
Cardiomyopathy	10 (10)	7 (7)	0 (0)	2 (6.1)	4 (13.8)	1 (5.9)
Previous PCI	2 (2)	4 (4)	1 (4.2)	0 (0.0)	3 (10.3)	0 (0.0)
Previous CABG	6 (6)	9 (9)	1 (4.2)	4 (12.1)	3 (10.3)	1 (5.9)
Previous arrhythmia	10 (10)	11 (11)	1 (4.2)	6 (18.2)	4 (13.8)	0 (0.0)
Arterial hypertension	60 (58)	65 (63)	13 (54.2)	16 (48.5)	24 (82.8)	12 (70.6)
Hyperlipidemia	17 (16)	32 (31)*	4 (16.7)	11 (33.3)	13 (44.8)	4 (23.5)
Previous TIA/stroke	8 (8)	10 (10)	0 (0)	5 (15.2)	3 (10.3)	2 (11.8)
Diabetes mellitus	44 (42)	40 (39)	6 (25)	14 (42.4)	13 (44.8)	7 (41.2)
Asthma/COPD	18 (17)	18 (17)	3 (12.5)	7 (21.2)	6 (20.7)	2 (11.8)
Active cancer	9 (9)	18 (17)	7 (29.2)	5 (15.2)	5 (17.2)	1 (5.9)
Prior history of cancer	3 (3)	2 (2)	1 (4.2)	1 (3.0)	0 (0.0)	0 (0.0)
ESRD	16 (15)	10 (10)	2 (8.3)	2 (6.1)	3 (10.3)	3 (17.6)
Moderate/severe liver disease	3 (3)	4 (4)	0 (0)	1 (3.0)	3 (10.3)	0 (0.0)
Dementia	2 (2)	2 (2)	1 (4.2)	0 (0.0)	1 (3.4)	0 (0.0)
Peripheral vascular disease	7 (7)	8 (8)	1 (4.2)	2 (6.1)	5 (17.2)	0 (0.0)
AIDS	0 (0)	3 (3)	0 (0)	2 (6.1)	0 (0.0)	1 (5.9)

* denotes a statistically significant value. All other values were not statistically significant. MI= myocardial infarction; PCI= percutaneous coronary intervention; CABG= coronary artery bypass graft; TIA= transient ischemic attack; COPD= chronic obstructive pulmonary disease; ESRD= end-stage renal disease; AIDS= acquired immunodeficiency syndrome.

research associates using a data dictionary to achieve consistency between collaborators.

The pre-intervention cohort consists of patients with an index arrest in the hospital (non-ICU, non-ED) during the one-year preceding August 1, 2016. The post-intervention cohort includes those with index arrest from August 1, 2016 to August 1, 2017 (1 year). Pre- and post-implementation data describing aforementioned patient and arrest characteristics was collected for all subjects to allow for comparison of pre- and post-intervention cohorts in 3, 6, 9, and 12-month captures. We compared pre- and post-intervention cohorts at each 3-month interval.

The primary outcome for our study was good neurological outcome as measured by the Pittsburgh Cerebral Performance Category (CPC) 1 or 2.[8] Secondary outcomes include return of spontaneous circulation (ROSC), survival to hospital discharge, and assessing outcomes differences over time. Descriptive statistics, including proportions (%), means (standard deviations [SD]), and medians (interquartile ranges [IQR]) are reported. Continuous data were tested for normality with the Shapiro Wilk test. Comparisons among cohorts were performed using the chi-square or Fisher's exact test for proportions and the Mann-Whitney U test for continuous variables. Two-sided p-values < 0.05 were considered significant. Analyses were performed with StatsDirect version 3.1.22 (StatsDirect Ltd, Cheshire, UK).

Results

Overall, the data was similar in both cohorts of patients. In the pre-team-focused CPR cohort vs post-team-focused CPR cohorts, mean age was 66 (SD 14) years and 63 (SD 17) years, respectively (p = 0.29). There were more men (p = 0.04) and patients with preexisting hyperlipidemia (p = 0.01) in the post-team-focused CPR cohort. Race and ethnicity were captured to allow us to explore the potential for contributions in cardiac arrest outcomes from both intrinsic and extrinsic sources. No difference in race or ethnicity were noted when comparing pre- and post-team-focused CPR cohorts.

All additional measured comorbidities were not significantly different between the two cohorts, as shown in Table 1.

Table 2 – Arrest characteristics.

	Pre-TFCPR (%) (n = 104)	TFCPR (%) (n = 103)	p-value	Q1 (%) (n = 24)	Q2 (%) (n = 33)	Q3 (%) (n = 29)	Q4 (%) (n = 17)
Location of Index Arrest*			0.01				
Inpatient ward	103 (99.0)	94 (91.3)		24 (100)	33 (100)	25 (86.2)	12 (70.6)
Inpatient, other	1 (1.0)	1 (1.0)		0 (0.0)	0 (0.0)	1 (3.4)	0 (0.0)
Radiology/Endoscopy	0 (0.0)	6 (5.8)		0 (0.0)	0 (0.0)	3 (10.3)	3 (17.6)
Unknown	0 (0.0)	2 (1.9)		0 (0.0)	0 (0.0)	0 (0.0)	2 (11.8)
Witnessed arrest							
Yes	69 (66.6)	76 (73.8)		15 (62.5)	28 (84.8)	23 (79.3)	10 (58.8)
Initial Rhythm							
Shockable	17 (16.3)	11 (10.7)		3 (12.5)	6 (18.2)	1 (3.4)	1 (5.9)
Non-shockable	87 (83.7)	92 (89.3)		21 (87.5)	27 (81.8)	28 (96.6)	16 (94.1)
Specific Initial Rhythm							
Ventricular fibrillation	9 (8.7)	6 (5.8)		2 (8.3)	3 (9.1)	0 (0.0)	1 (5.9)
Ventricular tachycardia	8 (7.7)	5 (48.5)		1 (4.2)	3 (9.1)	1 (3.4)	0 (0.0)
Asystole	19 (18.3)	17 (16.5)		5 (20.8)	6 (18.2)	6 (20.7)	0 (0.0)
Idioventricular/PEA	60 (57.7)	63 (61.2)		14 (58.3)	18 (54.5)	18 (62.1)	13 (76.5)
Unknown shockable	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Unknown non-shockable	8 (7.7)	12 (11.7)		2 (8.3)	3 (9.1)	4 (13.8)	3 (17.6)
Etiology of arrest							
Presumed cardiac	42 (40.4)	26 (25.2)		6 (25.0)	11 (33.3)	7 (24.1)	2 (11.8)
Presumed respiratory	23 (22.1)	27 (26.2)		5 (20.8)	4 (12.1)	13 (44.8)	5 (29.4)
Metabolic	2 (1.9)	2 (1.9)		1 (4.2)	1 (3.0)	0 (0.0)	1 (5.9)
Massive PE	1 (1.0)	3 (2.9)		2 (8.3)	0 (0.0)	0 (0.0)	1 (5.9)
Neurological	2 (1.9)	4 (3.9)		1 (4.2)	2 (6.1)	0 (0.0)	1 (5.9)
Hemorrhage, non-traumatic	1 (1.0)	6 (5.8)		1 (4.2)	3 (9.1)	1 (3.4)	1 (5.9)
Sepsis/septic shock	6 (5.8)	5 (3.9)		0 (0.0)	2 (6.1)	0 (0.0)	2 (11.8)
Unable to determine	27 (26.0)	31 (30.1)		8 (33.3)	10 (30.3)	8 (27.6)	3 (17.6)

* denotes a statistically significant value. All other values were not statistically significant. PEA= pulseless electrical activity; PE= pulmonary embolism.

Table 3 – Outcome of team-focused CPR vs standard CPR with index arrest in-hospital.

	Pre-team-focused CPR (%) (n = 104)	Post-team-focused CPR (%) (n = 103)	p-value	Q1 (%) (n = 24)	Q2 (%) (n = 33)	Q3 (%) (n = 29)	Q4 (%) (n = 17)
ROSC	76 (73.1)	81 (78.6)	0.35	18 (75)	29 (87.9)	21 (72.4)	13 (76.5)
Survival to hospital discharge	26 (25.0)	34 (33.0)	0.2	11 (45.8)	12 (36.4)	6 (20.7)	5 (29.4)
Survival with good neurological outcome	22 (21.1)	32 (31.1)	0.11	10 (41.7)	11 (33.3)	6 (20.7)	5 (29.4)

Initial location of arrest did differ between the two cohorts as shown in Table 2. One patient in the pre-team-focused CPR cohort arrested outside of the inpatient ward, compared to seven in the intervention cohort (p = 0.01). Six of these seven arrests occurred either in radiology or endoscopy. There was no significant difference between the two cohorts' additional arrest characteristics (e.g., witnessed, initial rhythm, or etiology of arrest).

For the primary outcome, there was no difference in good neurological outcome in the pre-team-focused CPR and post-team-focused CPR cohorts. Of the 104 patients before team-focused CPR initiation, survival with good neurological outcome was 21% compared to 31% in the 103 patients after team-focused CPR initiation [risk difference 9.9% (95% CI: −2 to 22%), p = 0.14]. See Table 3.

The secondary outcomes, ROSC rate and survival to hospital discharge were similar between the pre- and post-team-focused CPR cohorts with details outlined in Table 3. Overall survival prior to initiation of team-focused CPR was 25% compared to 33% in the year following initiation of team-focused CPR (p = 0.2).

When assessing for changes in outcomes over time, survival with good neurological outcome was 42% [(10/24 = 42%): risk difference 21% (95% CI: 1 to 42%), p = 0.05] in the 3-month period following team-focused CPR initiation. In the 6-month period following team-focused CPR initiation, survival with good neurological outcome was 37% [(21/57 = 37%): risk difference 16% (95% CI: 1 to 31%), p = 0.04]. There was no statistical change in survival with good neurological outcome when comparing the 9-month period or 12-month post-team-focused CPR period to the pre-team-focused CPR period. See Table 3.

Discussion

This single-site, retrospective before-and-after observational cohort study showed no differences in ROSC, survival, or good neurological outcomes with team-focused CPR implementation. However, there was an initial improvement in outcomes during the six months after team-focused CPR implementation that deteriorated over time. This improvement further corroborates the notion that this team-focused CPR IHCA initiative brings elements of education that echo important factors of ILCOR's Ten Step program. Hands-on, rehearsed training helps decrease human error to better both cardiac arrest care and patient outcomes.[6,16,17]

This improvement in outcomes during the first 6-months after team-focused CPR implementation with a subsequent decline may suggest a degradation in skill, knowledge, or execution as it relates to team-focused CPR may have occurred. Given that only a single training episode occurred in the months prior to team-focused CPR suggests the potential need for more frequent training intervals for this novel in-patient resuscitation pathway. The recent 2020 American Heart Association (AHA) CPR Guidelines recommend just this, with new additions under the umbrella of resuscitation education science encouraging the addition of deliberate practice and mastery learning as well as booster training and spaced learning.[9] While these are highly regarded recommendations, actual implementation and protocol approval to put in place such programs remains a challenge. In a 2021 study, only 15% of the 192 surveyed hospitals had a very active physician resuscitation champion; the rest of the hospitals had either a very active non-physician champion, a not active champion, or none at all.[3] The lack of leadership initiative in the field of resuscitation leaves some hospital staff confused and less than optimally trained, ultimately leading to worse IHCA outcomes. team-focused CPR is an attempt to ensure role clarity and a team-based approach to CPR. Setting goals to enact team-focused CPR booster training may be necessary to maintain the positive trend in post-arrest patient outcomes.

The AHA guidelines serve as a way to prioritize best-evidence for cardiac arrest resuscitation.[10] T eam-focused CPR is an established protocol that has proven effective for survival with good neurological outcome in OHCA patients that incorporates these recommendations while maintaining feasibility and the flexibility to be incorporated into any hospital.7 It helps standardize provider roles with an emphasis on evidence-based resuscitation goals including minimally interrupted high-quality CPR and early defibrillation. Based on the available evidence, this approach can translate into improved resuscitation of our patients within the hospital. When cardiac arrest occurs in the non-critical care units of the hospital, codes can be poorly structured and widely variable. team-focused CPR provides a uniform approach, as detailed in Fig. 1, for all hospital providers to focus on the importance of communication, skill development, and evidence-based practice with the intent to achieve optimal outcomes after cardiac arrest. Although this represents a model for a larger hospital with many responders, it can be adjusted to match available resources.

To our knowledge, this is the first time team-focused CPR has been initiated hospital-wide for IHCAs and therefore represents the first study exploring its impact. Prior studies, like Stopyra et al, assessed team-focused CPR's impact within a rural EMS system. Their data supported a drastic increase in ROSC achievement and survival to hospital admission but did not observe an increase in survival to hospital discharge.[11] A dual systematic review and meta-analysis exploring OHCA in Seoul, Korea demonstrated that "team CPR" improved survival to hospital discharge with good neurological outcome but no difference in achieving ROSC between the control and intervention cohorts.[12] Additionally, a 2020 qualitative analysis aimed to address experiences of healthcare providers responding to IHCAs.[13] Much of the dissatisfaction revolved around issues achieving closed-loop communication and with role identification and associated responsibilities.[13] Another study by Nallamathu et al. collected input from a diverse group of code responders pointed again to the struggle of communication and role delineation.[14] The four common themes of top-performing facilities included: designated resuscitation teams, multidisciplinary teams with clear roles, closed-loop communication and respectful leaders, and mock-code training.[14] team-focused CPR has been identified as a novel approach to team-based resuscitation with the potential to improve IHCA sequelae. We intend on integrating team-focused CPR throughout our enterprise for IHCA with more frequent training intervals and evaluating its impact on larger patient cohorts.

High-quality CPR and early defibrillation have been shown to increase survival rates.[10,15] Team-focused CPR is a choreographed, team-based approach to optimize CPR and defibrillation. While this study did not demonstrate outcomes differences, there might be a benefit with increased training frequency.[5] One randomized control trial assessed CPR performance at 1-, 3-, 6-, and 12- month training intervals.[5] The data revealed excellent CPR performance (58%) in trainees receiving monthly retraining with quality of CPR declining at each increased training interval; overall recommendations pointed to monthly training but did not address the feasibility of said schedule.[5]

Based on our study and analyzed data, retraining should occur every 6-months in order to mitigate potential degradation in outcomes. Future studies should be aimed at the practicality of more frequent retraining and its effect on survival and neurological outcome following IHCA.

Limitations

This study was performed at a single urban teaching hospital. CPC score was ascertained via chart review at time of discharge. We did not compare pre- vs post-intervention hospital length of stays which may have led to differing post-arrest times of neurological status assessment. Provider roles may vary with implementation of team-focused CPR in a different hospital setting, and results may vary based on hospital resources and personnel. The study was retrospective, and providers were not blinded to the intervention. With cohort sizes around 100, some basic characteristics such as sex, comorbidities, and location of arrest were significantly different between the two cohorts. The small patient cohorts also may have inadequate power to detect a difference. As this is a before and after study, advances in medicine and patient care may alter post-resuscitative care between the two cohorts.

Conclusion

In this single center observational cohort study, implementation of team-focused CPR for non-emergency department, non-intensive care unit in-hospital cardiac arrests did not show a difference in

return of spontaneous circulation, survival, or good neurological outcome at hospital discharge. However, neurological outcome was improved at 6 months after team-focused CPR deployment before declining towards baseline, suggesting potential opportunity for more frequent team training.

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Study Type: retrospective, prospective observational, investigator-initiated.

CRediT authorship contribution statement

David A. Pearson: Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization. **Nicole Bensen Covell:** Writing – original draft, Project administration, Investigation, Funding acquisition. **Benjamin Covell:** Writing – review & editing, Methodology, Investigation. **Blake Johnson:** Writing – review & editing, Methodology, Investigation. **Cate Lounsbury:** Writing – review & editing, Methodology, Investigation. **Mike Przybysz:** Writing – review & editing, Methodology, Conceptualization. **Anthony Weekes:** Writing – review & editing, Methodology, Conceptualization. **Michael Runyon:** Writing – review & editing, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: David A. Pearson, MD, MS, MBA; Advisor to Heartbeam, Inc.

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