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Quantitative analysis of duty cycle in pediatric and adolescent in-hospital cardiac arrest☆

Heather Wolfe[a,*], Ryan W. Morgan[a], Aaron Donoghue[a], Dana E. Niles[a], Peter Kudenchuk[b], Robert A. Berg[a], Vinay M. Nadkarni[a], Robert M. Sutton[a]

[a] The Children's Hospital of Philadelphia, Department of Anesthesiology and Critical Care Medicine, 34th Street and Civic Center Boulevard, Philadelphia, PA 19104, United States
[b] The University of Washington, Department of Medicine, Division of Cardiology, Seattle, WA 98195-6422, United States

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ABSTRACT

Aims: Quality cardiopulmonary resuscitation (CPR) is associated with improved outcomes during cardiac arrest. Duty cycle (DC) represents an understudied element of CPR quality. Our objective was to quantitatively analyze DC during actual pediatric and adolescent in-hospital cardiac arrest (IHCA).
Methods: Prospective observational study of IHCA at a large academic children's hospital. CPR variables included DC (%) up to the first 10 min of recorded chest compressions (CCs). American Heart Association (AHA) DC compliance was prospectively defined as an average event DC of 50 ± 5%. Percentage of events compliant with AHA DC was compared to *a priori* hypothesized compliance percentage of 25% using chi-square. Association between DC quartiles and categories of depth (<38, 38–49, ≥50 mm) and rate (<100, 100–120, >120 min^{-1}) were analyzed by chi-square test for trend.
Results: Between October 2006 and June 2015, 97 events in 87 patients were analyzed. Mean DC for events was 40 ± 2.8%. DC quartiles: Q1 (DC ≤38.3%), Q2 (>38.3–40.1%), Q3 (>40.1–42.1%), Q4 (>42.1%). Only 5 (5.2%) events met AHA DC compliance, significantly less than the *a priori* hypothesis of 25% ($p < 0.001$). Average CC rates trended higher across DC quartiles: (Q1) 105 ± 9; (Q2) 106 ± 9; (Q3) 112 ± 8; and (Q4) 118 ± 14 min^{-1}; $p < 0.001$. Other CPR quality variables were not associated with DC. There was no association between DC and survival.
Conclusions: Compression DC during resuscitation of actual child and adolescent IHCA met AHA recommendations in only 5% of events. In this series we found no association of DC with CC depth or survival.

Introduction

High quality cardiopulmonary resuscitation (CPR), including adequate chest compression depth, chest compression rate, chest compression fraction (CCF) and peri-shock pause have been associated with improvement in return of spontaneous circulation or survival to hospital discharge rates.[1–5] While these aspects of CPR are the most studied, other aspects of chest compression mechanics may have important influence on chest compression rate, depth, blood flow during CPR,[6] and patient survival.

To that end, duty cycle (DC), another component of CPR, is defined as the percentage of time spent during the down-stroke of compression.[7] Current recommendations from the American Heart Association (AHA) for DC is 50% in adult cardiac arrest and is based upon the best evidence available from animal and manikin studies, none of which showed association with improved outcome and any specific duty cycle.[8] None of the pediatric basic life support nor pediatric advanced life support documents since 2005 endorse a specific duty cycle for pediatric cardiac arrest.[8–11]

Until recently, there was little data evaluating DC during actual resuscitation attempts. A study of EMS providers measured duty cycle in relation to other CPR metrics from a cohort of adult patients with out-of hospital ventricular fibrillation arrests. They found that DC time delivered in clinical resuscitation was shorter than that recommended by the AHA, between 32 and 38%.[12] However, no clinical studies have described DC delivered in pediatric and adolescent cardiopulmonary resuscitation. Therefore, the aim of this

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* Corresponding author.
E-mail address: wolfeh@email.chop.edu (H. Wolfe).

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paper is to quantitatively describe DC during in-hospital pediatric and adolescent CPR and to determine its relationship to chest compression rate and depth. We hypothesize that actual pediatric CPR delivered will be compliant with AHA DC recommendations at least 25% of the time, and that DC will be inversely associated with CC rate (e.g., shorter DC will be associated with higher CC rate).[6,12]

Methods

Design, population and setting

This is a prospective observational study of patients who experienced in-hospital cardiac arrest between October 1, 2006 and June 30, 2015. Patients were treated in the emergency department (ED) or intensive care unit (ICU) equipped with a CPR enabled defibrillator with recording capability that was jointly designed by Phillips Heathcare (Andover, MA) and Laerdal Medical Corporation (Stavanger, Norway). Cardiac arrest events were identified through a cardiac arrest paging system with 94% event capture.[13] Cases were excluded if no defibrillator recording with quality of CPR data was available (i.e. defibrillator was not used during resuscitation). The Institutional Review Board at the Children's Hospital of Philadelphia approved this study protocol. Data collection procedures were completed in compliance with guidelines of the Health Insurance Portability and Accountability Act.

The study hospital is an academic, tertiary care pediatric facility with 516 inpatient beds. The ED has 70 beds and treats approximately 95,000 visits per year. The ICU is a combined medical-surgical unit (cardiac surgical patients are excluded) with 55 beds and approximately 3500 admissions per year. The team leader for ICU/ED cardiac arrests is either an ICU/ED fellow trainee or attending physician, however an attending physician is present for all arrests. In addition to the fellow and attending, response teams are comprised of 3–4 registered nurses, 1–2 respiratory therapists, and 1–2 resident physicians. An attending critical care and emergency physician are in-hospital 24 h per day and 7 days per week. All ICU/ED providers are pediatric advanced life support (PALS) certified and participate in frequent mock code and rolling refresher CPR training.[14,15] Starting in 2011, this group engages in multidisciplinary post-cardiac arrest debriefing after all significant chest compression events.[16]

Data collection

Data was collected in a prospective manner as a part of an in-hospital CPR quality improvement database. The Heartstart MRx defibrillator with Q-CPR option (Q: Quality), jointly designed by Philips Health Care (Amsterdam, Netherlands) and Laerdal Medical Corporation (Stavanger, Norway) was used to collect quantitative CPR data and provide real-time feedback if CPR was not meeting 2005 (2006–2011) or 2010 (2011–2015) AHA guidelines. The Heartstart MRx defibrillator is FDA approved for children ≥8 years, but we included patients less than 8 years of age for whom the defibrillator was used off-label at the discretion of the attending physician.[13] Laerdal Q-CPR technology was used to record and document CPR performance.

Outcome variables/analysis plan

The primary outcome variable was DC, reported as effective cycle time (ECT) and represents the percentage of time in compression during the entire compression-relaxation cycle. Secondary CPR quality variables included chest compression (cc) rate, cc depth and CPR fraction. Secondary survival outcomes included return of spontaneous circulation (ROSC) among all events and survival to hospital discharge among index events. Index events were defined as the first arrest for a subject if they had more than one in-hospital cardiac arrest in the study period. AHA DC compliance was defined as an average event DC of 50 ± 5%. Percentage of events compliant with AHA duty cycle was compared to an *a priori* hypothesized compliance percentage of 25% using chi-square. For the primary outcome variable and arrest characteristics, standard descriptive summaries, appropriate for underlying distribution of variables were calculated. Duty cycle was divided into quartiles in order to report the relationship between duty cycle and chest compression (cc) rate, CC depth as well as CPR fraction utilizing 30-s epochs. p value <0.05 was considered significant.

Each analyzed CPR event included all data from the first recorded compression up to the first ten minutes of recorded CPR. Each CPR event was analyzed in its entirety and also using 30-s epochs of CPR. A Microsoft Windows- based software program, Q-CPR Review (Version 2.1.0.0, Laerdal Medical, Stavanger, Norway), was used for initial examination and extraction of quantitative CPR quality data. Statistical analysis was completed using Stata (Version 12.0, StataCorp., College Station, TX).

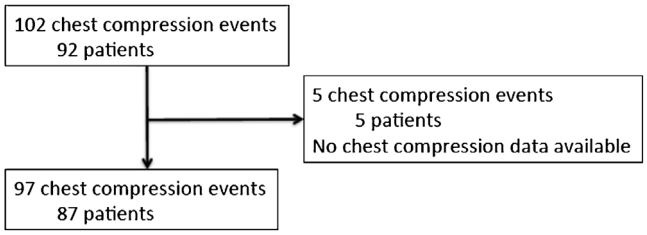

Fig. 1. Utstein style diagram.

Results

Events and patients

During the study, a total of 97 chest compression events with complete defibrillator CPR data were captured out of 102 total events (%). Of these 97 total events, 87 (%) represented index events (Fig. 1). Demographic and cardiac arrest event data are represented in Table 1. The majority of the cardiac arrests (68%) occurred in the Pediatric ICU. ROSC was obtained in 42% of patients, with 11% surviving to hospital discharge in the overall cohort.

Table 1
Patient demographic and cardiac arrest event data. ROSC, return of spontaneous circulation >20 min; PEA, pulseless electrical activity.

	Overall cohort
Subject demographic data	$n = 87$
Age: years mean ± SD	13.3 ± 5
Sex: male n (%)	42 (48)
Cardiac arrest event data	$n = 97$
Time of arrest n (%)	
Day/evening (7 AM–10:59 PM)	46 (47)
Night/weekends[a] (11 PM–6:59 AM)	51 (53)
Duration of CPR: minutes median (IQR)	11.6 (5.9–22.4)
Initial rhythm[b] n (%)	
Bradycardia	31 (32)
Asystole/PEA	52 (54)
Ventricular fibrillation	13 (13)
Pulseless ventricular tachycardia	
Survival n (%)	
Return of spontaneous circulation	42 (43)
Survival to hospital discharge	11 (11)

[a] Weekend indicates time between Friday 11 PM and Monday 6:59 AM.
[b] One patient missing initial rhythm.