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Cardiopulmonary resuscitation duty cycle in out-of-hospital cardiac arrest☆

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ABSTRACT

Background: Duty cycle is the portion of time spent in compression relative to total time of the compression–decompression cycle. Guidelines recommend a 50% duty cycle based largely on animal investigation. We undertook a descriptive evaluation of duty cycle in human resuscitation, and whether duty cycle correlates with other CPR measures.
Methods: We calculated the duty cycle, compression depth, and compression rate during EMS resuscitation of 164 patients with out-of-hospital ventricular fibrillation cardiac arrest. We captured force recordings from a chest accelerometer to measure ten-second CPR epochs that preceded rhythm analysis. Duty cycle was calculated using two methods. Effective compression time (ECT) is the time from beginning to end of compression divided by total period for that compression–decompression cycle. Area duty cycle (ADC) is the ratio of area under the force curve divided by total area of one compression–decompression cycle. We evaluated the compression depth and compression rate according to duty cycle quartiles.
Results: There were 369 ten-second epochs among 164 patients. The median duty cycle was 38.8% (SD = 5.5%) using ECT and 32.2% (SD = 4.3%) using ADC. A relatively shorter compression phase (lower duty cycle) was associated with greater compression depth (test for trend <0.05 for ECT and ADC) and slower compression rate (test for trend <0.05 for ADC). Sixty-one of 164 patients (37%) survived to hospital discharge.
Conclusions: Duty cycle was below the 50% recommended guideline, and was associated with compression depth and rate. These findings provider rationale to incorporate duty cycle into research aimed at understanding optimal CPR metrics.

1. Introduction

Cardiopulmonary resuscitation (CPR) – characterized by repeated chest compressions sometimes interspersed with rescue breathing – is a key link in the chain of survival designed to improve outcomes following cardiac arrest. Increasing evidence indicates that the specific composition of CPR can influence the likelihood of successful resuscitation. CPR characteristics such as compression depth, rate, extent of release (chest recoil), and timing (CPR interruptions) vary substantially in resuscitation, and this variability has been associated with the likelihood of survival and neurological recovery.[1] This evidence has formed the basis of resuscitation guidelines which provide specific goals for the different metrics of CPR (depth, rate, release, and timing).[2] This understanding has produced efforts directed toward training, CPR feedback (depth, rate, recoil), and mechanical CPR; all with the goal of improving outcomes following cardiac arrest.

Resuscitation guidelines also provide specific goals for the chest compression metric of "duty cycle". The CPR duty cycle is the proportion of time spent in compression relative to the total time of the compression plus decompression cycle.[2] Current CPR guidelines recommend a 50:50 duty cycle, where the time spent in compression and decompression is equal.[2] The recommendation is based on modest evidence derived largely from experimental and animal studies.[3–9] Little is known about duty cycle in human resuscitation

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and its relationship to other CPR metrics. We hypothesized that duty cycle would vary across individual arrests and would be correlated with other CPR metrics such as compression depth and rate.

2. Methods

2.1. Design, population, and setting

The study was a retrospective observational investigation of 164 persons who suffered non-traumatic, out-of-hospital ventricular fibrillation cardiac arrest between January 1, 2007 and December 31, 2011 and were treated by King County Emergency Medical Services (EMS) agencies equipped with specific recording equipment that monitored CPR performance. Cases were excluded if no defibrillator recording was available or the recording did not include measures of CPR throughout the resuscitation event. The investigation was approved by both the University of Washington and Public Health Review Boards. The study communities have a population of approximately 600,000 persons. The EMS is a 2-tier system activated by calling a central emergency dispatch (9-1-1) number. The first tier is comprised of EMT-firefighters equipped with automated external defibrillators. The second-tier is comprised of paramedics trained in advanced cardiac life support including ECG rhythm interpretation, drug administration, and endotracheal intubation. The EMS personnel generally follow the American Heart Association guidelines for cardiac arrest resuscitation.

2.2. Data collection and variables

The EMS system maintains a registry that includes every treated out-of-hospital cardiac arrest. Patient, circumstance, care, and outcome characteristics are abstracted from a range of sources including dispatch, EMS, hospital, vital statistics, and defibrillator records and organized according to the Utstein definitions.[10] The defibrillator information gathered for this particular study included a recording of the ECG rhythm tracing, the transthoracic impedance measurements, data from an accelerometer placed on the patient's chest, and the audio recording. The accelerometer data included measurements of acceleration and force which were used to compute chest compression rate and depth.

Chest compression duty cycle was calculated using the force recordings from the chest accelerometer, Philips MRx-Event Review Pro©, using two different previously reported methods termed the effective compression time (ECT) and area duty cycle (ADC). The force accelerometer can distinguish forces of compression from decompression. The ECT is a first-order measure that is the time from the beginning to the end of the compression divided by the total period for that compression–decompression event.[2] The ADC is a second-order measure that is the ratio between the area under the force curve and the total area of one rectangle outlining the compression–decompression curve (Fig. 1).[11] Thus the ECT is more intuitive measure of duty cycle but we also assessed the ACD in an effort to explore how different measures of force might compare to one another and to the compression metrics of depth and rate. The time period defining each compression period for ECT and ADC was defined as the time between the two absolute minima on either side of the compression peak in the force trace. Both measures are reported as percentages. These measures of duty cycle were derived using the ten-second CPR epochs that immediately preceded each scheduled defibrillator rhythm analysis set to occur at 2 min intervals per American Heart Association resuscitation guidelines. We calculated the median value of ECT and ADC for all compressions within the 10-s epoch.

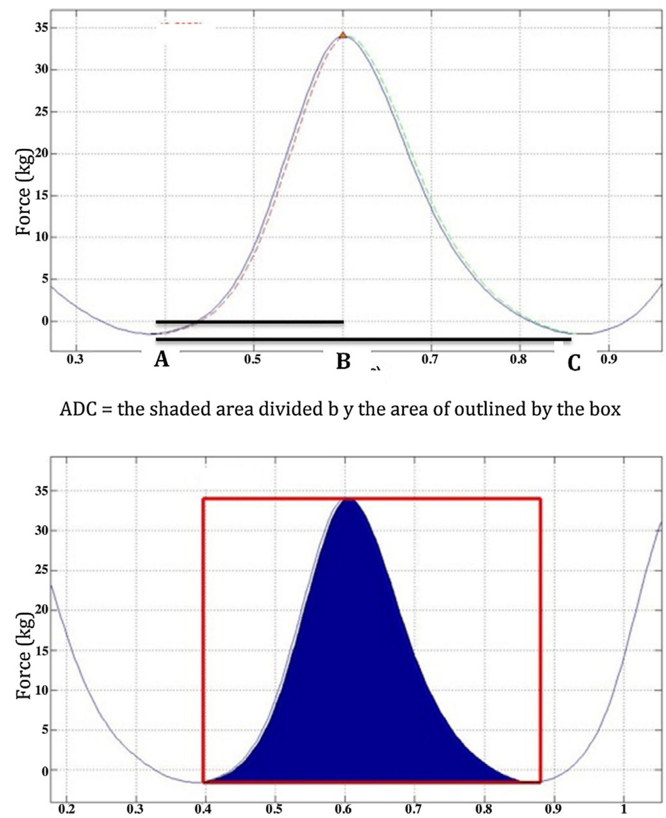

Fig. 1. Graphic depiction of duty cycle as derived from the ECT and ADC. The *y*-axis is the force and the *x*-axis is time.

Median depth values for each ten-second epoch were obtained directly from the MRx defibrillator download files, which record the depth for each CPR compression by estimating the position of the puck based on the acceleration measurements. Median chest compression rate was also calculated based on the force trace.

2.3. Statistical analysis

We used descriptive statistics to evaluate the distribution of the duty cycle. To characterize the relationships between duty cycle and the other CPR metrics parameters, we divided the duty cycle into quartiles. We then calculated compression depth and compression rate according to duty cycle quartiles. CPR metrics were calculated in MATLAB© and SPSS© statistics. Statistical significance was defined as $p < 0.05$.

3. Results

3.1. Patients

Of the 558 persons who suffered out-of-hospital ventricular fibrillation arrests and were treated by the study EMS agencies, 164 (29%) had complete defibrillator download information for the entire resuscitation event. Demographic, circumstance, care, and outcome characteristics were similar between cases included and excluded in the study (Table 1). Among study cases, most arrests were witnessed; more than half received bystander CPR; nearly two-thirds had spontaneous circulation at the end of EMS care, and about a third survived to hospital discharge with good neurological outcome (Table 1). Among witnessed ventricular fibrillation arrest due to presumed cardiac etiology (as designated by the Utstein