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Clinical paper

Amplitude-spectral area and chest compression release velocity independently predict hospital discharge and good neurological outcome in ventricular fibrillation out-of-hospital cardiac arrest☆

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ABSTRACT

Objective: In out-of-hospital cardiac arrest (OHCA) with ventricular fibrillation (VF) the frequency-based waveform characteristic, amplitude-spectral area (AMSA) is associated with hospital discharge and good neurological outcome, yet AMSA is also known to increase in response to chest compressions (CC). In addition to rate and depth, well performed CC provides good chest recoil without leaning, reflected in the release velocity (RV). We hypothesized that AMSA is associated with hospital discharge and good neurological outcome independent of CC quality.
Methods: OHCA patients (age ≥ 18), with initial rhythm of VF from an Utstein-Style database were analyzed. AMSA was measured prior to each shock, and averaged for each subject (AMSA-avg). Primary endpoint was hospital discharge and secondary endpoint was a good neurological outcome. Univariate and stepwise multivariable logistic regression, and receiver–operator–characteristic (ROC) analyses were performed. Factors analyzed were age, sex, witnessed status, time from dispatch to monitor/defibrillator application, number of shocks, first shock AMSA ($AMSA_1$), AMSA-avg, averaged pre-shock pause, CC rate, depth, and RV.
Results: 140 subjects were analyzed. Hospital discharge was 31% and with good neurological outcome in 24% (77% of those discharged). AMSA-avg ($p < 0.001$), RV ($p = 0.002$), and age ($p = 0.029$) were independently associated with hospital discharge, with a non-significant trend for witnessed status ($p = 0.069$), with AUC = 0.846 for the multivariate model. For good neurological outcome, AMSA-avg ($p = 0.001$) and RV ($p = 0.001$) remained independently significant, with AUC = 0.782.
Conclusion: In OHCA with an initial rhythm of VF, AMSA-avg and CC RV are both highly and independently associated with hospital discharge and good neurological outcome.

1. Introduction

Improvements in survival for out-of-hospital cardiac arrest (OHCA) parallels advances in resuscitation that include the availability of automated external defibrillators and post-resuscitation care with therapeutic hypothermia and early percutaneous coronary intervention [1]. In particular chest compressions of adequate rate and depth, and avoidance of prolonged peri-shock or pre-shock pauses are associated with improved outcomes [2,3,4]. Additionally, leaning during the performance of chest compressions gives incomplete chest recoil and has a deleterious effect on hemodynamics in animal models [5]. Leaning commonly occurs among rescuers [6,7,8,9] and therefore the avoidance of leaning was specifically identified as a CPR quality metric by the American Heart Association [10]. This has motivated the study of the release velocity as a quantitative measure of adequate chest recoil, and human data has linked a high release velocity to improved outcomes [11].

Nonetheless, patients with seemingly similar cardiac arrest Utstein characteristics and post resuscitation care can have drastically different outcomes. It remains unclear what other features

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may explain these differences in survival. In an investigation of 390 patients with VF cardiac arrest [12], the amplitude-spectral area (AMSA) measured from the VF waveform indicated survival with a good neurological outcome. This was confirmed in a cohort of witnessed VF cardiac arrest in Arizona that showed AMSA was associated with hospital discharge and identified a threshold for AMSA below which survival was highly unlikely [13]. AMSA also predicted long term survival in a recently reported cohort in Italy [14].

However, these studies did not account for chest compressions. It is known that AMSA rises with well-performed chest compressions in both animal [15,16,17] and human studies [18,19]. This raises the question whether it is solely chest compression quality that predicts outcome or whether the VF waveform can add independent predictive value. Our hypothesis was that the VF waveform parameter AMSA is associated with hospital discharge and good neurological outcome in out of hospital VF cardiac arrest, and independent of chest compression quality.

2. Methods

Resuscitation data from adult patients with witnessed OHCA was collected through the Saving Hearts in Arizona Registry and Education (SHARE) Program, a previously described statewide Utstein-style database [20]. Out-of-hospital cardiac arrest has been designated a major public health problem by the Arizona Department of Health Services. SHARE is the designated public health program created to measure response to out-of-hospital cardiac arrest and improve outcomes. Thus, the SHARE Program initiatives and its data collection are exempt from the Health Insurance Portability and Accountability Act. By virtue of SHARE being a health department-sponsored public health initiative, the Arizona Department of Health Services' Human Subjects Review Board and the University of Arizona institutional review board have determined that neither the interventions nor their evaluation constitutes human subjects research and have approved the publication of deidentified data.

Data was taken from two sites in Arizona participating in the SHARE Program, from the dates of September 4, 2008 through June 30, 2011. The methodology for data collection in the SHARE database has been described previously [20,21,22]. Inclusion criteria were OHCA in patients at least 18 years with resuscitation initiated in the field and initial rhythm of VF. Return of spontaneous circulation (ROSC) was defined as a confirmed pulse for at least 5 min. A subset of this database of 89 subjects with witnessed arrest has been previously reported [13], with 2 additional witnessed arrest subjects identified upon review and included in the current analysis. The primary endpoint was hospital discharge, and the secondary endpoint was a good neurological outcome, defined as a Cerebral Performance Category score of 1 (good cerebral performance) or 2 (moderate cerebral disability).

Chest compression (CC) indices and VF waveform data were downloaded from the monitor/defibrillator (E Series monitor/defibrillator, ZOLL Medical Corporation. CC data included the compression rate (cpm = compressions/minute), compression depth (in.) and release velocity (RV) (mm/s), which was measured through an accelerometer that is integrated into the defibrillator pads, and averaged over time for each patient [22]. CPR data was acquired throughout the time that the pads were in place. Release velocity was computed as the peak release velocity during each compression. Chest compression indices were acquired from throughout the entire resuscitation event. Pre-shock pause was computed as the number of seconds without CC prior to shock, averaged for each patient.

Electronic waveform data were recorded from the defibrillator pads with a sampling rate of 250 samples/sec. Waveform data were then downloaded to an ASCII file and analyzed with customized software (MATLAB). A time segment of VF of 4.1 s in duration (N = 1024 datapoints) was chosen prior to each shock, within 10 s of that shock and visually free of artifact including chest compressions. (EMS personnel were not instructed to deliberately hold compressions.) Amplitude-spectral area (AMSA), was then computed as previously described [13], and in brief is the summed product of frequency, F_i, and amplitude, A_i, over a frequency interval of 4 to 48 Hz (resolved in frequency steps of 250/N Hz):

$$\text{AMSA} = \left(\frac{1}{N}\right)\sum_{i} = A_i \times F$$

This formulation has the advantage of yielding stable and consistent values of AMSA even if computed for an N other than 1024 (i.e. 512 or 2048 datapoints). We chose the frequency range from 4 to 48 Hz in accordance with other published studies [15,23]. AMSA was averaged over all shocks within that subject (AMSA-avg). In a subject with only one shock, AMSA-avg by definition was equal to the value of the first shock AMSA. AMSA prior to the first shock, AMSA_1, was also analyzed. AMSA data therefore were collected at discrete timepoints, namely just prior to shocks, whereas CC quality indices were obtained and averaged over the entire resuscitation event.

3. Statistics

Data are presented as mean ± standard deviation. Differences in the means of continuous variables were assessed by Student's t test, and differences in proportion for categorical variables by a chi-square test. Significance was set to p = 0.05.

Logistic regression was performed to determine factors that were predictive of the primary endpoint of hospital discharge and secondary endpoint of good neurological outcome. Factors that were analyzed, a-priori, were age, sex, number of shocks, time from EMS dispatch to connection of the monitor/defibrillator, compression rate, compression depth, RV, pre-shock pause, AMSA_1, and AMSA-avg. Factors with a p value less than 0.1 in a univariate analysis were then incorporated into a backward-selection stepwise multivariate regression analysis. Significance of factors was determined by a likelihood-ratio test, and data is presented as the odds ratio (OR) with 95% confidence interval [95% CI]. A receiver–operator characteristic (ROC) curve analysis was performed to determine the area under the curve (AUC) of the tested factors to predict hospital discharge in the univariate and multivariate regression models. A probability curve as a function of AMSA-avg was computed from the multivariate regression model adjusting other continuous variables to their mean values and stratified by witnessed status. Data were analyzed with the statistical program, STATA (StataCorp LP, College Station, TX).

4. Results

There were 143 adult OHCA cases with an initial rhythm of VF of which two cases were excluded for incomplete data (survival outcome not recorded) and one case was excluded for excessive artifact and loss of contact of the defibrillation pads. Thus 140 cases were analyzed, 104 men and 36 women. Average age was 62 ± 14 years and 91 cases (65%) were witnessed. Median number of shocks per subject was 3 with a range of 1 to 11. Pre-hospital ROSC was attained in 57 subjects (41%), of whom 6 did not survive to hospital admission. Hospital admission occurred in 72 subjects (51%), of whom 21 had not achieved pre-hospital ROSC. Hospital discharge occurred in 44 subjects (31%), and with good neurological outcome in 34 (24%). Thus 77% of those discharged from the hospital had a good neurological status (Fig. 1).