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Clinical paper

Does the choice of definition for defibrillation and CPR success impact the predictability of ventricular fibrillation waveform analysis?☆

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ABSTRACT

Background: Quantitative analysis of ventricular fibrillation (VF), such as amplitude spectral area (AMSA), predicts shock outcomes. However, there is no uniform definition of shock/cardiopulmonary resuscitation (CPR) success in out-of-hospital cardiac arrest (OHCA). The objective of this study is to investigate post-shock rhythm variations and the impact of shock/CPR success definition on the predictability of AMSA.
Methods: A total of 554 shocks from 257 OHCA patients with VF as initial rhythm were analyzed. Post-shock rhythms were analyzed every 5 s up to 120 s and annotated as VF, asystole (AS) and organized rhythm (OR) at serial time intervals. Three shock/CPR success definitions were used to evaluate the predictability of AMSA: (1) termination of VF (ToVF); (2) return of organized electrical activity (ROEA); (3) return of potentially perfusing rhythm (RPPR).
Results: Rhythm changes occurred after 54.5% (N = 302) of shocks and 85.8% (N = 259) of them occurred within 60 s after shock delivery. The observed post-shock rhythm changes were (1) from AS to VF (24.9%), (2) from OR to VF (16.1%), and (3) from AS to OR (12.1%). The area under the receiver operating characteristic curve (AUC) for AMSA as a predictor of shock/CPR success reached its maximum 60 s post-shock. The AUC was 0.646 for ToVF, 0.782 for ROEA, and 0.835 for RPPR ($p < 0.001$) respectively.
Conclusions: Post-shock rhythm is unstable in the first minute after the shock. The predictability of AMSA varies depending on the definition of shock/CPR success and performs best with the return of potentially perfusing rhythm endpoint for OHCA.

Introduction

Cardiac arrest is a major public health problem around the world.[1] Despite the reported decreased incidence of ventricular fibrillation (VF) as presenting rhythm during the last decades, it is believed to be the initial rhythm in out-of-hospital cardiac arrest (OHCA) for the majority of sudden cardiac arrests with a cardiac cause.[2] Early defibrillation in conjunction with cardiopulmonary resuscitation (CPR) may allow for return of spontaneous circulation (ROSC) after OHCA with a shockable rhythm.[3] Current guidelines emphasize the quality of CPR and recommend that chest compressions should be resumed immediately after a defibrillation attempt and continued for 2 min before reassessing for ROSC or the need for re-attempted defibrillation.[4,5] However, the optimal chest compression duration prior to delivery of shock for individual patients is unknown since not all patients in VF may benefit equally from being treated according to purely time-based protocols.[6]

Optimized shock timing can reduce unnecessary interruptions of chest compressions and decrease the severity of post-resuscitation myocardial dysfunction by reducing the number of failed or unnecessary shocks, which potentially could improve overall survival from cardiac arrest.[7] The prediction of successful defibrillation would allow adjustment of the resuscitation protocol to the condition of the patient, rather than using fixed time intervals in universally applied treatment protocols.[8] To develop a

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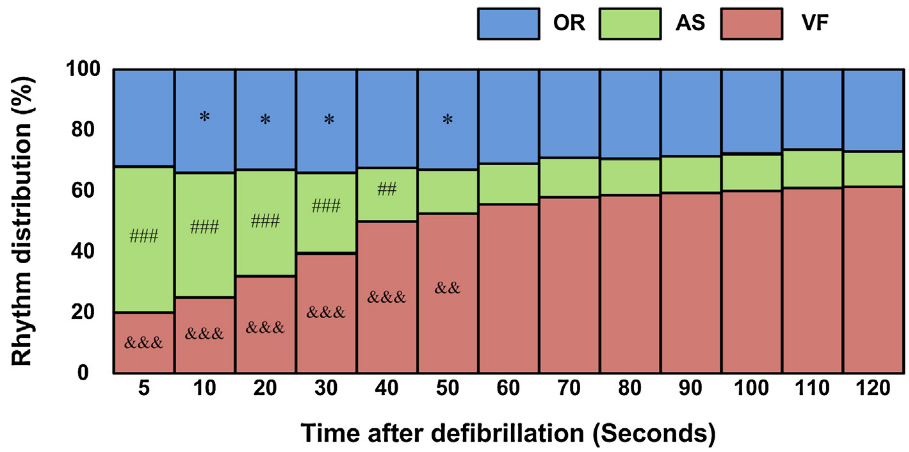

Fig. 1. Distribution of post-shock rhythms (N = 581). OR: Organized rhythm, AS: asystole, VF: ventricular fibrillation. *: Compared with distribution of OR at 120 s, $p < 0.05$; ## and ###: compared with distribution of AS at 120 s, $p < 0.01$ and $p < 0.001$; && and &&&: compared with distribution of VF at 120 s, $p < 0.01$ and $p < 0.001$.

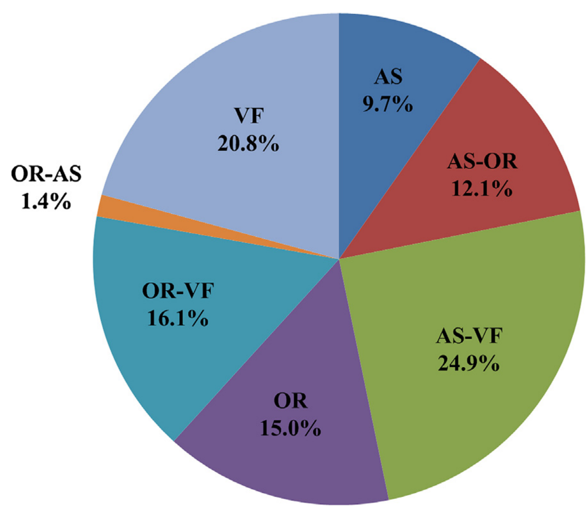

Fig. 2. Rhythm changes observed within 120 s after defibrillation (N = 581). OR: Organized rhythm, AS: asystole, VF: ventricular fibrillation, AS-OR: rhythm changed from AS to OR, AS-VF: rhythm changed from AS to VF, OR-VF: rhythm changed from OR to VF, OR-AS: rhythm changed from OR to AS.

patient-based resuscitation therapy incorporating CPR and defibrillation requires a sensitive indicator that predicts defibrillation outcomes.

Characteristics of the VF waveform, which change over time and with CPR, show potential for prognostication of defibrillation.[9] Amplitude spectrum area (AMSA), which uses a summed product of VF frequency and signal amplitude, has been shown to be one of the most accurate predictors for successful defibrillation in retrospective clinical studies.[10–12] Although AMSA has been demonstrated to be promising for the prediction of defibrillation outcome and could be a useful approach to optimize the timing of defibrillation, lack of a uniform definition of shock/CPR success makes comparison between potentially useful predictors difficult.[13–18] In the present study, we used a registry database of OHCA to investigate rhythm variations following shock delivery and the impact of shock/CPR success definition on the predictive ability of AMSA.

Methods

Data collection

Pre-hospital ECGs along with CPR compression data were collected between March 2005 and October 2008 from 10 emergency medical system (EMS) in the USA through a regular field case submission program sponsored by ZOLL Medical Corporation. Only those data that were from adult patients with presenting shockable rhythms and resumption of chest compressions after shock delivery were included for analysis. Approval for this retrospective review study was obtained from all participating systems. ECG and compression depth signals were simultaneously recorded from a pair of standard adhesive adult defibrillation/pacing pads with an integrated accelerometer sensor for CPR feedback (CPR-D-padz, ZOLL Medical Corporation, Chelmsford, MA, USA). All the EMSs in this study used ZOLL automated external defibrillators (AEDs), which employ a rectilinear biphasic waveform. All the electronic data had their patient identifiable information removed prior to being submitted to the registry database.

Waveform annotation and analysis

ECGs were recorded at a sample rate of 250 Hz. RescueNet Code Review (Enterprise Edition 5.21, ZOLL Medical Corporations, Chelmsford, MA, USA), which is a software program used to display and analyze the resuscitation events, was used to show all the events prior to and after delivery of each electrical shock. All ECG waveforms were extracted by RescueNet Code Review and analyzed using Matlab (version 7.2, MathWorks, Natick, MA). Waveform data from the pre-shock pause with a duration of 2.05 s ending 0.5 s before each shock was used to calculate pre-shock AMSA.[8] Post-shock rhythms were annotated at 5 s intervals up to 120 s after each shock. A 5 s analysis window was used to identify the presence of VF, asystole (AS), or organized rhythm (OR) at each time interval. AS was defined as a 'flat line' ECG with peak-to-peak amplitude <0.1 mV, OR was classified if one or more apparent QRS complexes occurred within the analysis window. If rhythm transition occurred within the analysis window, the rhythm after transition was used as the annotated rhythm. The rhythm observed 2 min after the defibrillation attempt served as the final rhythm. The annotation scheme was performed by two medical doctors with the aid of an algorithm we developed to filter out CPR related artifacts.[19] The process was not entirely dependent on the output of the algorithm because filtering out CPR-related artifact is still imperfect and sometimes very difficult for discrimination of non-shockable rhythms.[20] Only rhythms for which there was consensus between the doctors who were blinded to the purpose of the studies were included.

To study the impact of definition of shock/CPR success on the predictive value of AMSA, we used 3 slightly modified different criteria previously described in the literature: (1) termination of VF