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Clinical paper

Dual defibrillation in out-of-hospital cardiac arrest: A retrospective cohort analysis☆

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ABSTRACT

Study objectives: The goal of our study is to determine if prehospital dual defibrillation (DD) is associated with better neurologically intact survival in out-of-hospital cardiac arrest.
Methods: This study is a retrospective cohort analysis of prospectively collected Quality Assurance/Quality Improvement data from a large urban fire based EMS system out-of-hospital cardiac arrest (OHCA) database between Jan 2013 and Dec 2015. Our inclusion criteria were administration of DD or at least four conventional 200J defibrillations for cases of recurrent and refractory ventricular fibrillation (VF). We excluded any case with incomplete data. The primary outcome for our study was neurologically intact survival (defined as Cerebral Performance Category 1 and 2).
Results: A total of 3470 cases of OHCA were treated during the time period of Jan 2013 to Dec 2015. There were 302 cases of recurrent and refractory VF identified. Twenty-three cases had incomplete data. Of the remaining 279 cases, 50 were treated with DD and 229 received standard single shock 200J defibrillations. There was no statistically significant difference in the primary outcome of neurologically intact survival between the DD group (6%) and the standard defibrillation group (11.4%) ($p = 0.317$) (OR 0.50, 95% CI 0.15–1.72).
Conclusion: Our retrospective cohort analysis on the prehospital use of DD in OHCA found no association with neurologically intact survival. Case–control studies are needed to further evaluate the efficacy of DD in the prehospital setting.

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Introduction

Background

In the setting of out-of-hospital cardiac arrest (OHCA), the presence of a shockable rhythm is associated with better outcomes.[1,2] The primary therapy for patients with ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT) is defibrillation.[3] However, the best defibrillation strategy for patients that do not achieve return of spontaneous circulation within the first few rounds of cardiopulmonary resuscitation remains unclear.[3–6] A small subset of this patient population has recurrent or refractory VF. The age-adjusted annual incidence of refractory VF is estimated to be between 0.5 and 0.6 cases per 100,000 people.[7] Due to its rarity and lack of a standard definition, there are no currently established best practices for this difficult to treat condition.

Double sequential defibrillation (DSD) is postulated to be a solution to the dilemma of recurrent/refractory VF and pulseless VT.[8] In DSD, the "double" refers to the use of two separate defibrillators on the same patient; "sequential" refers to the administration of nearly simultaneous defibrillations from both devices. In the absence of electronically connected and synchronized defibrillation devices, true DSD is not possible in our prehospital system. We utilize the dual defibrillation (DD) technique, where the operator delivers nearly simultaneous defibrillations from two separate devices. Multiple techniques for DSD have been described: small 1–2 s delays between the delivery of sequential shocks,[8] precisely synchronized shocks with small overlaps,[9,10] and simultaneous delivery from two devices by a single individual.[11,12]

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The mechanism for DSD's hypothesized clinical benefit focuses primarily on overcoming the defibrillation threshold. There is evidence that suggests that delivering sequential shocks may lower the defibrillation threshold compared to a traditional single shock.[13,14] Alternatively, others hypothesize that defibrillation is a weight based treatment and larger individuals simply may require more joules.[15,16] The last leading theory for DSD efficacy is that the therapy changes the vector of the therapy and the shock is given over a longer duration.[8] DSD was first developed and tested in canine models of refractory VF.[9,10,17] Hoch et al. reported a small observational study attesting to the safety and efficacy of DSD's in the setting of refractory VF and pulseless VT during routine electrophysiology testing.[8] Double sequential defibrillation continues to be used sporadically by electrophysiologists to treat refractory VF.[12]

Emergency Medical Services (EMS) physicians struggle with the decision whether or not to transport patients with refractory and recurrent VF. First, it is well documented that the quality of CPR in a moving ambulance is reduced.[18,19] Second, transporting patients who do not attain return of spontaneous circulation (ROSC) in the field may exceed the acceptable rate of medical futility.[20] Prehospital DD may indeed provide an answer to this controversy in management. However, in the setting of out-of-hospital cardiac arrest (OHCA) it is a novel and unproven therapy.[21]

Importance

There are two small case series and one case report describing the use of DD in the prehospital setting with varying levels of success.[22–24] However, there have been no comparisons of DD with conventional therapy.

Goals of this investigation

The goal of our study is to determine if prehospital DD is associated with better neurologically intact survival in out-of-hospital cardiac arrest.

Materials and methods

Study design and setting

This study is a retrospective cohort analysis of prospectively collected Quality Assurance/Quality Improvement (QA/QI) data. The data was obtained from the San Antonio Fire Department (SAFD) OHCA QA/QI database between Jan 2013 and Dec 2015. The study was designed to adhere to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[25] Our study was approved by the University of Texas Health Science Center at San Antonio (UTHSCSA) Institutional Review Board.

The SAFD is the sole 911 provider for a population of approximately 1.4 million people spread over a 460-square-mile area. Medical direction for the SAFD is provided by the UTHSCSA Department of Emergency Health Services' Office of the Medical Director (OMD). All online medical direction is provided by EMS physicians and fellows. The SAFD deploys a four-person fire company and two dual-paramedic-staffed mobile intensive care ambulances to all OHCA calls. Approximately, half the fire companies in the SAFD are staffed with at least one paramedic qualified firefighter and all carry an Automated External Defibrillator (AED).

During the study period, the protocol of SAFD EMS was to consider DD after administering three 200J conventional defibrillations during an OHCA resuscitation for both cases of refractory VF and recurrent VF. In our system both refractory VF, which we defined as persisting in VF during the resuscitation, and recurrent VF, which we defined as potentially terminating VF but then returning to VF at some time during the resuscitation, are potentially treated with DD. The decision to administer a DD was left to the discretion of the lead paramedic on the resuscitation. In our system, we utilized two sets of pads attached to two external defibrillators (Zoll X series Defibrillator, Chelmsford, MA). One set of pads was placed in an anterior–posterior arrangement, and the other to the right of the sternum and over the apex. The shock delivery buttons were pushed simultaneously by one person, delivering a total energy of 400J.

Selection of participants

The cohort was derived from all SAFD OHCA cases between Jan 2013 and Dec 2015. Our inclusion criteria were administration of DD or at least four conventional 200J defibrillations. We excluded any case with incomplete data. We included both cases of refractory VF and recurrent VF as we considered this a more realistic real world test of double sequential defibrillation since that is how it is operationalized in our system and the distinction between refractory VF and recurrent VF can be difficult to ascertain during the resuscitation.

Interventions

The intervention was DD during OHCA.

Methods of measurement

The SAFD OMD utilizes an internal OHCA database as part of our OHCA QA/QI program. Our database captures a wide variety of variables including patient demographic information, resuscitative efforts, and patient outcomes. The database is populated by mandatory crew debriefings, review of the electronic patient care report (ePCR), and interrogation of equipment as needed. Each OHCA ePCR is reviewed and a standardized interview conducted by an OMD staff member of the OHCA resuscitation team leader as soon as practical after the event. Relevant data elements are pulled from the ePCR as well as the interview. Patient outcome data is also collected from any patient transported to hospitals for further care. Hospital records, obituary reviews, and the Social Security Death Index are used to determine hospital survival.

Two authors (E.R. and J.M.) extracted the cases from our OHCA QA/QI database. They were blinded to the outcomes of the patients, but not to the study hypothesis when they derived the cohort.

Outcomes

The primary outcome for our study was neurologically intact survival to hospital discharge. Neurologically intact survival is defined as Cerebral Performance Category (CPC) 1 and 2. Secondary outcomes were prehospital ROSC, survival to hospital admission, and survival to hospital discharge.

Analysis

Our team used chi-square and Fisher's exact test to examine the association between DD and our identified outcomes. Statistical significance was defined as $p < 0.05$. We utilized an odds ratio to estimate the magnitude of the effect that double sequential defibrillation had on our identified outcomes. Where appropriate, 95% Confidence Intervals were calculated. Microsoft Excel (Microsoft Corp., Redmond, WA) was used to manage the data. We analyzed the data with Graph Pad Prism 6 (Graphpad Software, Inc., La Jolla, CA) and MedCalc online odds ratio calculator (MedCalc Software bvba, Ostend, Belgium).

Results

Characteristics of study subjects

A total of 3470 cases of OHCA were treated during the time period of Jan 2013 to Dec 2015 (Fig. 1). There were 302 cases of recurrent and refractory VF identified. Twenty-three cases had incomplete data. Of the remaining 279 cases, 50 were treated with DD, and 229 received standard 200J defibrillations (SD). There were no statistically significant differences between the groups with respect to average age (59 years (95% CI 55.3–63.6) in DD and 61 years (95% CI 59.5–63.4) in SD ($p = 0.39$)), gender (76% men in DD vs. 73% in SD group ($p = 0.86$), rate of bystander CPR (30% in DD vs. 45% in SD group ($p = 0.06$)), or rate of public automated external defibrillator (AED) use (6% in DD vs. 3.5% in the SD group ($p = 0.42$)). The only statistically significant difference between the groups was percentage of witnessed arrest with 38% in the DD group vs. 54.6% in the SD group ($p = 0.04$).

Main results

The primary outcome of neurologically intact survival showed no statistically significant difference in the two groups with 6% in the DD group and 11.4% ($p = 0.317$) (OR 0.50, 95% CI 0.15–1.72) in the SD group (Tables 1 and 2). Secondary outcomes of ROSC by EMS, 28% vs. 37.6% ($p = 0.255$) (OR 0.65, 95% CI 0.33–1.27), survival to hospital admission 32% vs. 35.4% ($p = 0.744$) (OR 0.86, 95% CI 0.45–1.65), and survival to hospital discharge, 8% vs. 14.4% ($p = 0.356$) (OR 0.52, 95% CI 0.17–1.53) were also not statistically significant.

Additional subgroup analysis was conducted on the DD patients and 26 were identified as meeting criteria for refractory VF. No statistically significant difference in outcomes was noted between this subgroup and the group with standard care alone for neurologic outcomes 7.7% vs. 11.4% ($p = 0.749$), ROSC by EMS, 23.1% vs. 37.6% ($p = 0.196$), survival to hospital admission 38.5% vs. 35.4% ($p = 0.830$) or survival to hospital discharge 11.5% vs. 14.4% ($p = 0.777$).

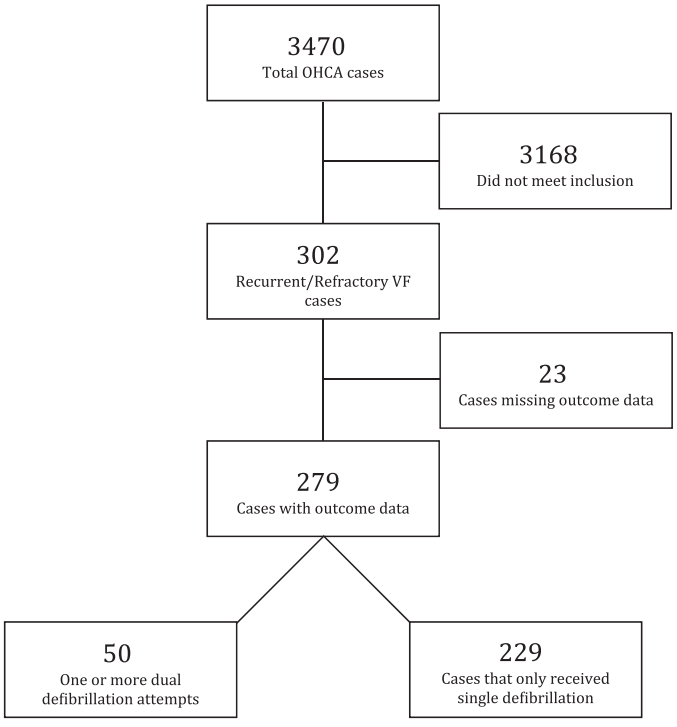

Fig. 1. There were 302 cases from the cardiac arrest database that met inclusion criteria for recurrent or refractory ventricular fibrillation (VF). 23 cases were excluded as they were missing outcome data. Of the 279 remaining cases of recurrent/refractory VF, 50 received at least one dual defibrillation attempt. The remaining cases received only single shocks.

Table 1
Demographic information and results about the two groups, DD and those receiving single shocks only. For the primary outcome of interest, neurologic survival with CPC 1 or 2, the result was not statistically significant. None of the secondary outcomes were statistically significant.

	Dual defibrillation	Single defibrillation only	*p* value
Mean age	59.4	61.4	0.39
% Male	76.0%	73.4%	0.86
% Witnessed arrest	38.0%	54.6%	0.04
% Bystander CPR	30.0%	45.4%	0.06
% Public AED use	6.0%	3.5%	0.42
Primary outcome			
CPC 1 or 2	3/50	26/229	0.32
Secondary outcomes			
ROSC by EMS	14/50	86/229	0.25
Survival to hospital admission	16/50	81/229	0.74
Survival to hospital discharge	4/50	33/229	0.36

Table 2
Odds ratios and 95% confidence intervals for the primary and secondary outcomes of interest.

	Odds ratio	95% CI
Primary outcome		
CPC 1 or 2	0.50	0.15–1.72
Secondary outcomes		
ROSC by EMS	0.65	0.33–1.27
Survival to hospital admission	0.74	0.45–1.65
Survival to hospital discharge	0.52	0.17–1.53

Limitations

Our study has limitations. This is an observational study and is prone to selection bias. Our protocol left the decision to administer double sequential defibrillation to the lead paramedic. This protocol structure increases the possibility of an unknown confounding variable causing bias. Additionally, our EMS system is a large, highly resourced advanced life support (ALS) response system. Two monitor defibrillators are routinely available at our OHCA cases. Smaller EMS systems may have to divert additional ambulances to provide DD in the prehospital setting. Data fidelity was not complete in the existing OHCA database for some of the relevant data elements. As a result of the omitted data, 7.5% of the relevant patient population was not eligible for inclusion. This missing data is a possible source of information bias. We used both refractory VF and recurrent VF patients within our analysis as a reflection of our current protocol and practice. However, if the benefit for DD is only seen in the smaller refractory VF population, this combined group would skew the data toward no difference. The use of inter-connected dual synchronized defibrillators was not possible making the true separation of the dual defibrillation unknown, but even in previously published studies, there has been no clearly identified best practice or technique. Lastly an important data element that has been previously reported that was not obtainable in our data set, was the number of defibrillation attempts prior to double sequential defibrillation. While many patients may have received the DD as early as the fourth shock according to the protocol, the timing of the DD shock could not be confirmed.

Discussion

We found no statistically significant difference in primary or secondary outcomes when comparing the two groups. In a subgroup analysis of only refractory VF we also found no difference between patient outcomes. Generally, the dual defibrillation and standard care group were well matched with no statistically significant differences in age, sex, rate of bystander CPR or early AED use.

There were more patients in the single defibrillation group with witnessed arrest and bystander CPR, with only the former attaining statistical significance. A witnessed arrest is associated with improved survival.[2] However, this fact did not translate into any difference in our primary or secondary outcomes of the study. These factors may be confounders in the outcomes of interest for the two groups.

Our results differ from a recent case series on the prehospital use of double sequence defibrillation in refractory VF patients. Merlin et al. reported ROSC rates of 57.1% and neurologically intact survival of 28.6%.[22] To date, the only published data on double sequential defibrillation in the prehospital environment have been case series and case reports.[22–24] The current study is the first to compare the outcomes of standard therapy and dual defibrillation in the out-of-hospital setting.

The true impact of double sequential defibrillation remains unclear in the absence of a well designed prospective study. However, given its age-adjusted annual incidence between 0.5 and 0.6 cases per 100,000 people an appropriately powered prospective trial may not be feasible. Given these constraints, a case control study is a reasonable option to further evaluate the efficacy of double sequential defibrillation.

In summary, our retrospective cohort analysis on the prehospital use of DD in OHCA found no association with neurologically intact survival. Case–control studies are needed to further evaluate the efficacy of DD in the prehospital setting.

Disclaimer

The views expressed in this article are those of the author(s) and do not necessarily reflect the official policy or position of the Department of the Navy, the Department of the Army, Department of Defense, or the United States Government. "I am a military service member. This work was prepared as part of my official duties. Title 17, USC, §105 provides that 'Copyright protection under this title is not available for any work of the U.S. Government.' Title 17, USC, §101 defines a U.S. Government work as a work prepared by a military service member or employee of the U.S. Government as part of that person's official duties."

Conflict of interest statement

None of the authors have conflicts of interest to disclose. This project had no sponsors and did not receive any funding support.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2016.06.011.

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