Effectiveness of Prehospital Dual Sequential Defibrillation for Refractory Ventricular Fibrillation and Ventricular Tachycardia Cardiac Arrest

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ORIGINAL CONTRIBUTIONS

EFFECTIVENESS OF PREHOSPITAL DUAL SEQUENTIAL DEFIBRILLATION FOR REFRACTORY VENTRICULAR FIBRILLATION AND VENTRICULAR TACHYCARDIA CARDIAC ARREST

Lauren R. Beck, BS, Daniel G. Ostermayer, MD, Joseph N. Ponce, BS, Saranya Srinivasan, MD, Henry E. Wang, MD, MS

ABSTRACT

Objective: Dual sequential defibrillation (DSD) — successive defibrillations with two defibrillators — offers a novel approach to refractory ventricular fibrillation (RVF) and tachycardia (VF/VT). While associated with rescue shock success, the effect of DSD upon out-of-hospital cardiac arrest (OHCA) is unknown. We evaluated the association of DSD with survival after refractory VF/VT OHCA.

Methods: We used data from a large metropolitan fire-based EMS service. We included all adult OHCA during 2013–2016 with ≥3 standard defibrillations. Physicians authorized subsequent DSD use by two separate defibrillators (PhysioControl LIFEPAK® 12/15) with pads placed anterior-lateral and anterior-posterior. Evaluated outcomes included return of spontaneous circulation (ROSC), survival to hospital admission, survival to 72 hours, and survival to hospital discharge. Using multivariable logistic regression, we evaluated the association between defibrillation type and OHCA outcomes, adjusting for patient demographics and event characteristics.

Results: We included 310 patients in the analysis, 71 patients receiving DSD and 239 receiving conventional defibrillation. Patient demographics and event characteristics were similar between both groups. ROSC was lower for DSD than standard defibrillation: 39.4% vs. 60.3%, adjusted OR 0.46 (95% CI: 0.25–0.87). There were no differences in survival to hospital admission (35.2% vs. 49.2%, adjusted OR 0.57 [95% CI: 0.30–1.08]), survival to 72 hours (21.4% vs. 32.3%, adjusted OR 0.52 [95% CI: 0.26–1.10]), or survival to hospital discharge (14.3% vs. 20.9%, adjusted OR 0.63 [95% CI: 0.27–1.45]).

Conclusions: Compared with conventional defibrillation, DSD was associated with lower odds of prehospital ROSC. Defibrillation type was not associated with other OHCA endpoints. DSD may not be beneficial in refractory VF/VT OHCA.

Key words: cardiac arrest; defibrillation; refractory ventricular fibrillation; double sequential defibrillation

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INTRODUCTION

Background

Out-of-hospital cardiac arrest (OHCA) is a public health problem in the United States, affecting more than 350,000 persons annually with an overall survival of only 12% (1). The primary treatment for ventricular fibrillation (VF) cardiac arrest is defibrillation. In select cases, ventricular fibrillation may be refractory to standard defibrillation (2).

Dual sequential defibrillation (DSD) is a novel treatment for refractory ventricular fibrillation (RVF) (3–6). DSD entails the placement of two sets of defibrillation pads in opposing positions on the torso, with the rapid application of sequential rescue shocks. Several mechanisms have been proposed for the improved effects of DSD. The use of multiple
pads may expand the defibrillation vector, increasing the ability to overcome the electrical threshold for defibrillation. The application of an additional set of defibrillation pads may also allow for depolarization of a larger mass of myocardium compared with standard defibrillation (3–5). The increased electrical vector may compensate for any user error or physiologic obstructions that would normally lower the efficacy of standard defibrillation (5). Case series describe increased rescue shock success with the use of DSD (7).

Importance

While case series suggest increased rescue shock success with DSD, there have been no studies associating its use with improved return of spontaneous circulation or survival to hospital discharge.

Objective of the Study

In this study we sought to determine the association between DSD and patient outcomes after refractory VF OCHA.

Methods

Study Design

This study used retrospective data from the Houston Fire Department (HFD), a large Metropolitan fire-based EMS service. The study was approved by the Committee for Protection of Human Subjects of the University of Texas Health Science Center at Houston with waiver of the requirement for informed consent.

Study Setting

HFD is a two-tiered 9-1-1 EMS system with BLS and ALS units. HFD serves a geographic area totaling 2.3 million persons and 667 sq. miles in the greater Houston region. The agency sees 300,000 EMS calls annually. No other EMS agencies provide emergency 9-1-1 response within Houston city limits. HFD has 3,500 prehospital providers, all of whom are trained as firefighters and have at least Basic Life Support Emergency Medical Technician (EMT) training. HFD also has 700 paramedics providing ALS care. Dispatch of the initial unit is determined based on the 9-1-1 call type and severity (8).

Selection of Subjects

We obtained prehospital records from HFD for all patients who experienced an OHCA from January 2013 to December 2016, the four-year period where DSD was used by HFD. We obtained prehospital treatment and patient outcome data from the ImageTrend® patient care report (ImageTrend, Lakeville, MN) software system, HFD direct medical oversight telemetry reports, and the HFD cardiac arrest care follow-up database. For each case we created a timeline of the cardiac arrest care episode, including defibrillations, medication administration, airway placement, and the number and type of defibrillation provided. We included patients with RVF, defined as patients’ refractory to 3 or more sequential defibrillation attempts.

Interventions: Delivery of DSD

The DSD protocol consisted of the application of two Physio Control Lifepak series 12 or 15 Defibrillators (Physio-Control, Redmond WA). While not protocolized, typical pad placement was anterior-lateral and anterior-posterior. Execution of DSD consisted of discharge of both defibrillators simultaneously. DSD shocks were biphasic at 360 joules each (720J summative). There were no limits to the number of applied DSD shocks. All other aspects of cardiac arrest care followed local protocol.

DSD use was guided and initiated by on-line medical command. During each cardiac arrest the Houston Emergency Center Telemetry Base Station facilitates communication with an on-call medical director. If the patient appeared to be in RVF, the medical director was permitted to order DSD attempts. Online medical control was contacted for all cardiac arrests prior to transport or consideration of field termination.

Outcomes and Clinical Variables

The primary outcomes of interest were prehospital return of spontaneous circulation (ROSC), survival to hospital admission, survival to 72 hours, and survival to hospital discharge. These outcomes are determined by HFD from contact with each hospital as part of ongoing quality assurance efforts and incorporated into a database. We identified other clinical variables obtained from prehospital patient care records. Patient demographics included age and gender. Event characteristics included the witnessed arrest, use of bystander CPR, initial arrest rhythm, supraglottic airway and intubation placement, number of defibrillations, and drug administration.
Data Analysis

We divided the study patients into two groups: those receiving DSD and those receiving standard defibrillation. We used descriptive statistics to characterize patients in each exposure group. To determine associations between defibrillation and outcomes, we used multivariable logistic regression models. We fit each outcome (ROSC, survival to hospital admission, survival to 72 hours, and survival to discharge) as the dependent variable, and defibrillation type (DSD vs standard) as the primary independent variable. We adjusted the model for age, sex, witness status, bystander CPR, initial arrest rhythm, intubation, supraglottic airway placement, and standard shocks post-DSD. We conducted all analyses using Stata v.14.1 (Stata, Inc., College Station, TX).

RESULTS

From January 1, 2013 to December 31, 2016, we identified 314 cases of OHCA with RVF based on the telemetry reports. As shown in Figure 1, we excluded three of these cases due to missing ImageTrend care reports. All three of these cases experienced DSD attempts. One additional case was excluded because the patient was less than 18 years of age. This patient did not receive DSD. Of the remaining 310 cases, 71 cases received at least one DSD attempt and 239 cases received solely standard defibrillation.

The average age of the patients in both treatment groups was 62 years old, and both treatment groups contained more men than women. (Table 1) Most patients in each group experienced bystander witnessed arrest. Bystander CPR occurred in 54% of DSD group and 49% of standard defibrillation. The initial arrest rhythm for the DSD group was shockable (VF/VT) in 94% of the cases.

In the standard defibrillation group, patients received a mean of 4.7 standard 360J rescue shocks. The patients in the DSD received a mean of 4.5 standard 360J rescue shocks followed by 2.2 DSD. Thirteen DSD patients received at least one standard rescue shock after DSD failed. The DSD patients received higher doses of epinephrine when compared to the standard defibrillation group: 8.2 mg vs. 6.2 mg (difference -2.0 [95% CI: -3.1, -0.9]).

ROSC was achieved by 39% of the DSD group and 60% of the standard defibrillation group (adjusted OR 0.46 [95% CI: 0.25-0.87]). (Table 2) There was no difference in survival to hospital admission (DSD 35% vs. standard defibrillation 49%, adjusted OR 0.57 [95% CI: 0.30-1.08]). There were similarly no differences in seventy-two-hour survival (adjusted OR 0.52 [95% CI: 0.26-1.10]) or survival to hospital discharge (adjusted OR 0.63 [95% CI: 0.27-1.45]) between DSD and standard defibrillation.

DISCUSSION

In this observational study, the odds of prehospital ROSC were significantly lower for patients treated with DSD than those treated with only standard defibrillations. Furthermore, there were no differences in survival to hospital admission, 72-hour survival or survival to hospital discharge between DSD and standard defibrillation. These observations suggest that there is no clear benefit from DSD over standard defibrillation.
Prior studies have suggested benefits from DSD. Cortez et al. showed 25% rates of ROSC and survival for DSD with a sample size of only 12 DSD patients (5). A case series by Merlin et al. also showed higher rates of survival for DSD patients with 3 out of 7 patients surviving to hospital discharge (7). These two studies show rates of survival for DSD patients that are higher than those seen in either intervention group in this study, likely due to their small sample size.

Other studies have shown no significant difference in outcomes when using DSD. A study by Ross et al. comparing DSD patients (n = 50) to patients who received at least four conventional defibrillations (n = 229), showed no difference in ROSC (28% vs. 37.6%) or other survival outcomes (9). A similar observational study comparing DSD patients (n = 45) to patients who received 6 or more standard shocks (n = 175), showed similar rates of ROSC between both treatment groups (38% vs. 35%) (10). For both Ross et al. (9) and Emmerson et al. (10), rates of ROSC are consistent with those seen in the DSD treatment group in this study. The difference in ROSC rates for the standard defibrillation group is likely due to different selection criteria used (3 vs. 4 or 3 vs. 6 defibrillations).

### Table 1. Patient demographics and event characteristics for out-of-hospital cardiac arrest (OHCA) patients, stratified by who received double sequential defibrillation (DSD) vs. standard defibrillation only

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>DSD (N = 71)</th>
<th>Standard defibrillation group (N = 239)</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62.2 ± 14.1</td>
<td>62.3 ± 14.3</td>
<td>0.1 (0.37–3.9)*</td>
</tr>
<tr>
<td>Sex (male), n (%)</td>
<td>61 (84.5)</td>
<td>174 (72.80)</td>
<td>2.03 (0.98–4.56)</td>
</tr>
<tr>
<td>Time to scene (minutes)</td>
<td>5.6 ± 2.0</td>
<td>5.5 ± 2.2</td>
<td>−0.1 (−0.6 to 0.5)*</td>
</tr>
<tr>
<td>Witnessed arrest, n (%)</td>
<td></td>
<td></td>
<td>0.77 (0.56–1.06)</td>
</tr>
<tr>
<td>Bystander witnessed</td>
<td>52 (73.2)</td>
<td>149 (62.3)</td>
<td></td>
</tr>
<tr>
<td>EMS witnessed</td>
<td>4 (5.6)</td>
<td>20 (8.4)</td>
<td></td>
</tr>
<tr>
<td>Not witnessed</td>
<td>15 (21.1)</td>
<td>70 (29.3)</td>
<td></td>
</tr>
<tr>
<td>Bystander CPR, n (%)</td>
<td>38 (53.5)</td>
<td>118 (49.4)</td>
<td>1.18 (0.67–2.08)</td>
</tr>
<tr>
<td>Initial arrest rhythm, n (%)</td>
<td>64 (94.1)</td>
<td>258 (99.6)</td>
<td>0.07 (0.00–0.70)</td>
</tr>
<tr>
<td>Shockable (VF/VT)</td>
<td>4 (5.9)</td>
<td>1 (0.4)</td>
<td></td>
</tr>
<tr>
<td>Not Shockable (PEA/asystole)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraglottic airway placed, n (%)</td>
<td>40 (56.3)</td>
<td>145 (60.7)</td>
<td>0.84 (0.47–1.49)</td>
</tr>
<tr>
<td>Intubation attempted, n (%)</td>
<td>53 (74.7)</td>
<td>193 (80.75)</td>
<td>0.70 (0.36–1.39)</td>
</tr>
<tr>
<td>Median intubation attempts</td>
<td>1.0</td>
<td>1.0</td>
<td>0.18*</td>
</tr>
<tr>
<td>Intubation successful, n (%)</td>
<td>51 (69.2)</td>
<td>178 (92.7)</td>
<td>2.00 (0.44–18.71)</td>
</tr>
<tr>
<td>Number of EMS rescue shocks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All rescue shocks</td>
<td>6.7 ± 2.3</td>
<td>4.7 ± 1.9</td>
<td>−2.0 (−2.6 to −1.5)*</td>
</tr>
<tr>
<td>Standard rescue shocks</td>
<td>4.5 ± 2.1</td>
<td>4.7 ± 1.9</td>
<td>0.2 (−0.3, 0.7)*</td>
</tr>
<tr>
<td>DSD rescue shocks</td>
<td>2.2 ± 1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-DSD standard shocks, n (%)</td>
<td>13 (18.57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean epinephrine administration (mg)</td>
<td>8.2 ± 4.2</td>
<td>6.2 ± 3.9</td>
<td>−2.0 (−3.1 to −0.9)*</td>
</tr>
<tr>
<td>Total amiodarone administration, n (%)</td>
<td></td>
<td></td>
<td>1.01 (1.00–1.01)</td>
</tr>
</tbody>
</table>

*Difference (95% CI).

†P-value for rank sum test.

### Table 2. Outcome characteristics for out-of-hospital cardiac arrest (OHCA) where double sequential defibrillation (DSD) or three or more standard defibrillations was used

<table>
<thead>
<tr>
<th>Patient outcome</th>
<th>DSD N (%) (N = 71)</th>
<th>Standard defibrillation N (%) (N = 239)</th>
<th>Unadjusted Odds Ratio (95% CI)</th>
<th>Adjusted Odds Ratio (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return of spontaneous circulation (ROSC)</td>
<td>28 (39.4)</td>
<td>144 (60.3)</td>
<td>0.43 (0.24, 0.76)</td>
<td>0.46 (0.25, 0.87)</td>
</tr>
<tr>
<td>Survival to hospital admission</td>
<td>25 (35.2)</td>
<td>117 (49.2)</td>
<td>0.56 (0.32, 1.00)</td>
<td>0.57 (0.30, 1.08)</td>
</tr>
<tr>
<td>Survival to 72 hours</td>
<td>15 (21.4)</td>
<td>76 (32.3)</td>
<td>0.57 (0.28)</td>
<td>0.52 (0.26, 1.10)</td>
</tr>
<tr>
<td>Survival to hospital discharge</td>
<td>10 (14.3)</td>
<td>49 (20.9)</td>
<td>0.63 (0.27, 1.37)</td>
<td>0.63 (0.27, 1.45)</td>
</tr>
</tbody>
</table>

*Adjusted odds ratio accounts for age, sex, witnessed arrest, bystander CPR, initial arrest rhythm, intubation attempted, supraglottic airway placement, and standard shocks post-DSD.
Contrary to the aforementioned studies, in a case series by Cabanas et al., zero of the ten patients who received DSD survived to hospital discharge (3). The patients in Cabanas et al. (3) did not receive DSD until a median of 6.5 unsuccessful standard defibrillations. This underscores the idea that standardized timing of the defibrillations is necessary for DSD to be effective. Our study contrasts previous studies in the inclusion of a larger series of patients with systematic linkage to clinical outcomes.

There are plausible explanations for the absence of DSD effect observed in this study. We limited DSD application to those who failed at least 3 conventional rescue shocks and required authorization via on-line medical direction only. Patients in the DSD group received a greater number of shocks due to the addition of the DSD and continued RVF in comparison to the patients with standard resuscitation where ROSC occurred more frequently. DSD may be more efficacious if used earlier and by standing protocol, which would decrease time delays, and limit provider variability in potentially important procedural steps such as defibrillator pad placement, timing of the sequential defibrillator discharges, and coordination with antidysrhythmics and medication epinephrine dosing. Also, the time spent positioning the patient for placement of a complimentary set of defibrillator pads may have disrupted CPR and added unnecessary complexity to an already prolonged resuscitation.

Although defibrillation at the second VF/VT may offer the possibility for greater chance at reducing RVF, a more measured approach to treating RVF may involve a few differing pharmacologic therapies. Although patients received less amiodarone in the standard defibrillation group due to earlier prehospital ROSC modifying myocardial irritation could assist in decreasing the duration of RVF. Limiting the amount of myocardial irritation with decreased epinephrine dosing, stimulating beta 2 receptors with agonists, or elongating the ventricular refractory period using alpha-1 receptor agonists (norepinephrine or phenylephrine) may offer a longer refractory period using alpha-1 receptor agonists, or elongating the ventricular refractory period using alpha-1 receptor agonists (norepinephrine or phenylephrine) may offer a longer refractory period using alpha-1 receptor agonists may offer a greater opportunity to prevent RVF (11, 12). The study agency used PhysioControl LifePak defibrillators, which delivers a biphasic truncated exponential waveform; different results may have occurred with the use of defibrillators from different manufacturers which utilize a biphasic rectilinear waveform.

This study supports previous findings that DSD is likely not more beneficial than standard defibrillations for obtaining ROSC or improving survival outcomes. While all the current data is retrospective, the advantage of DSD is not apparent. Case studies have shown DSD to be a feasible technique, but this has not translated into association with improved outcomes in retrospective cohort analysis. Continued use of DSD for RVF requires support from a RCT demonstrating benefits under controlled conditions. The implementation of an RCT could help clarify the ideal protocol and patient population for which DSD would be effective.

The most important limitations of our study are its retrospective design and potential assignment bias. A far greater number of patients received standard single defibrillations compared to the DSD group. However, all cases, DSD or standard received direct medical oversight from the same pool of physicians. The ideal study would entail randomized application of DSD, with consideration given to timing of DSD relative to other ACLS interventions and neurologic outcomes. Other limitations include the absence of pad placement details. This agency’s generally accepted practice involved adding the additional DSD pad set to the complimentary position of the initial pads (AP or lateral) but specifics were not consistently documented for this dataset. Although, the medical directors agreed on the possible usefulness of the therapy, reasons for not authorizing were not documented and may have included but not limited to, perceived futility due to prolonged resuscitation, faulty equipment, or patient size limiting pad placement. Differences in pad placement could have altered the effectiveness of the DSD.

The timing of DSD was also not standardized and may be more or less efficacious if discharged in parallel or series. Also, CPR compression fractions could not be ascertained from this dataset and may have differed between the groups, especially among those without ROSC with prolonged resuscitation as providers tired with manual CPR and attempted transport. It is possible that there was also incomplete case ascertainment during the four-year study period.

**Conclusions**

In this observational study, DSD was associated with lower odds of ROSC compared with standard defibrillation. The use of DSD was not associated with OHCA outcomes. DSD may not be beneficial in case of refractory VF/VT OHCA.

**References**


