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Clinical paper

The impact of double sequential external defibrillation on termination of refractory ventricular fibrillation during out-of-hospital cardiac arrest

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Abstract

Background: Despite significant advances in resuscitation efforts, there are some patients who remain in ventricular fibrillation (VF) after multiple shocks during out-of-hospital cardiac arrest (OHCA). Double sequential external defibrillation (DSED) has been proposed as a treatment option for patients in refractory VF.

Objective: We sought to explore the relationship between type of defibrillation (standard vs DSED), the number of defibrillation attempts provided and the outcomes of VF termination and return of spontaneous circulation (ROSC) for patients presenting in refractory VF.

Methods: We performed a retrospective review of all treated adult OHCA who presented in VF and received a minimum of three successive standard defibrillations over a three-year period beginning on January 1, 2015 in four Canadian EMS agencies. Using ambulance call reports and defibrillator files, we compared rates of VF termination (defined as the absence of VF at the rhythm check following defibrillation and two minutes of CPR) and VF termination to ROSC for patients who received standard defibrillation and those who received DSED (after on-line medical consultation). Cases with public access defibrillation, those with do not resuscitate orders, and those who presented in VF but terminated VF prior to three shocks were excluded.

Results: Of the 252 patients included, 201 (79.8%) received standard defibrillation only and 51 (20.2%) received at least one DSED. Overall, VF termination was similar between standard defibrillation and DSED (78.1% vs. 76.5%; RR: 1.0; 95% CI: 0.8–1.2). In our shock-based analysis, when early defibrillation attempts were considered (defibrillation attempt 4–8), VF termination was higher for those receiving DSED compared to standard defibrillation (29.4% vs. 17.5%; RR: 1.7; 95% CI: 1.1–2.6). Overall, VF termination to ROSC was similar between standard defibrillation and DSED (21.4% vs. 17.6%; RR: 0.8; 95% CI: 0.4–1.6). Additionally, when early defibrillation attempts were considered (defibrillation attempt 4–8), ROSC was higher for those receiving DSED compared to standard defibrillation (15.7% vs. 5.4%; RR: 2.9; 95% CI: 1.4–5.9). When late defibrillation attempts were considered (defibrillation attempt 9–17), VF termination was higher for those receiving DSED compared to standard defibrillation (31.2% vs. 17.1%; RR: 1.8; 95% CI: 1.1–3.0), but ROSC was rare regardless of defibrillation strategy. When DSED terminated VF into ROSC, it did so with a single DSED attempt in 66.7% of cases.

Conclusions: Our observational findings suggest that while overall VF termination and ROSC are similar between standard defibrillation and DSED, earlier DSED may be associated with improved rates of VF termination and ROSC compared to standard defibrillation for refractory VF. A randomized controlled trial is required to assess the impact of early application of DSED on patient-important outcomes.

Keywords: Cardiopulmonary resuscitation, Heart arrest, Resuscitation, Double sequential external defibrillation

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Introduction

Out-of-hospital cardiac arrest (OHCA) accounts for over 350,000 unexpected deaths each year in North America; nearly 100,000 of which are attributed to ventricular fibrillation or pulseless ventricular tachycardia (VF/VT).[1] VF/VT is considered the most treatment-responsive presentation of cardiac arrest and boasts the highest rate of survival. However, despite significant advances in resuscitation efforts such as CPR quality, defibrillation, airway management, and antiarrhythmic medications given in hopes of promoting the return of an organized rhythm, there are some VF patients who are in "refractory" VF. Refractory VF has been defined as patients presenting with an initial rhythm of VF who remain in VF without response to multiple standard defibrillation attempts.[2,3] Refractory VF differs from recurrent VF, which has been defined as VF that reoccurs after successful termination of a VF waveform.[4] The survival outcomes for patients in refractory VF are 4.9%–12.7%, much lower compared to survival in recurrent VF which range from 21.4% to 29.3%.[5–8]

Double sequential external defibrillation (DSED) has been studied for decades in the electrophysiology lab for patients in both refractory atrial fibrillation and refractory VF.[9–16] The exact mechanism by which patients respond to DSED remains unknown. Animal studies have suggested that rapid sequential defibrillations may reduce the defibrillation threshold.[11] Transthoracic impedance has also been found to be decreased by sequential defibrillations, resulting in higher current density at the cardiac surface.[14,16]

Recently published case reports and multiple case series have described conflicting outcomes for patients treated with DSED for refractory VF.[17–23] Cabanas et al., were able to demonstrate improved termination of VF employing a prehospital protocol using DSED, but reported no improvement in hospital survival, likely due to late application of the intervention.[17] In a retrospective analysis of 50 DSED cases over a three-year time frame, Ross et al., reported no improvement in the primary outcome of neurologically intact survival with DSED, but did not include data regarding the timing of the DSED shock or CPR quality.[18] Similar findings were noted by Beck et al. but as well did not include data regarding the timing of the DSED shock nor CPR quality provided.[19] The authors note that "DSD may be more efficacious if used earlier and by standing protocol". On the contrary, Lybeck et al., and Johnson et al., both described case reports of early use of DSED with successful outcomes of neurologically intact survival to hospital discharge.[20,21]

The findings of this preliminary work suggest that further research is warranted to better understand the potential impact of DSED for the management of refractory VF. Further, most uses of DSED have been employed as an ad-hoc final effort to convert refractory VF, as opposed to a planned early application, and many of the previous studies did not report the timing of DSED. The objective of this study was to explore the relationship between type of defibrillation (standard vs DSED), the number of defibrillation attempts provided and the outcomes of VF termination and VF termination with return of spontaneous circulation (ROSC) for OHCA patients presenting in refractory VF.

Methods

Setting and design

We performed a retrospective review of prospectively collected data on treated adult (≥18 years) OHCA who presented in VF and received a minimum of three successive standard defibrillations over a three-year period beginning on January 1, 2015 in four EMS agencies in Ontario, Canada. The agencies (Peel Regional Paramedic Service, Halton Region Paramedic Service, Simcoe Paramedic Service and Toronto Paramedic Service) provide emergency care and transport to a population of 4.8 million people in both urban and rural settings within a geographic area of 7680 km^2. Paramedics in these regions treat over 4000 OHCA per year. Prehospital medical care is provided by advanced care paramedics (full advanced life support skills) and primary care paramedics (basic life support skills with the addition of a small number of medications and manual defibrillation).

For all patients meeting the study inclusion criteria, full ALS care (standard defibrillation, intubation or supraglottic airway insertion, antiarrhythmic medication and epinephrine) was provided. Beginning in January 2015, paramedics could request authorization from a physician via on-line medical control to perform DSED for patients who had not responded to standard defibrillation. There was no mandated "patch point" during the resuscitation when paramedics were required to call for DSED. The decision to request authorization for DSED was made by the senior paramedic on scene. When DSED was performed during a resuscitation, a second set of defibrillation pads were applied to the patient in the anterior–posterior (AP) position in addition to the pre-existing defibrillation pads that were in the anterior–anterior position (AA), as per Fig. 1. When shocks were provided during DSED, they were provided in a rapid sequential manner (single paramedic pressing the shock button on the original defibrillator followed by pressing the shock button of the second defibrillator) to negate any risk of defibrillator damage previously reported with simultaneous DSED.[24]

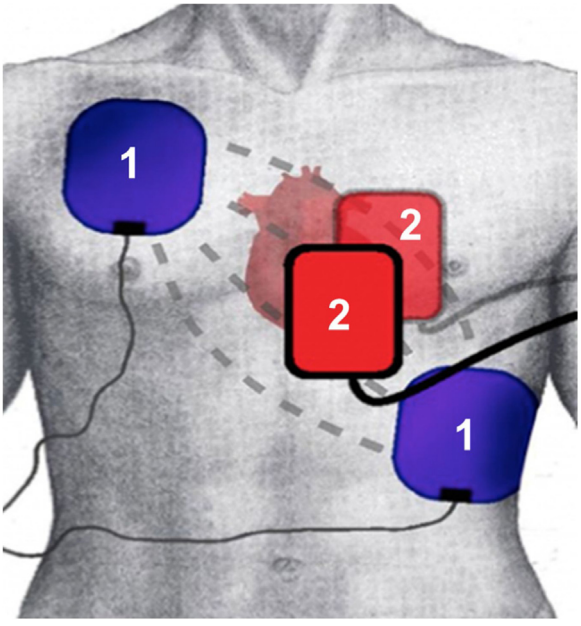

Fig. 1 – Pad placement for double sequential external defibrillation. Where blue (#1) defibrillation pads indicate pad placement in the anterior–anterior position and red (#2) defibrillation pads indicate pad placement in the anterior–posterior position.

Study population

Patients eligible for this study included those 18 years of age and older who sustained non-traumatic OHCA of presumed cardiac etiology and presented in VF. Patients had to receive three successive standard defibrillation attempts and remain in VF at the time of the fourth rhythm analysis to be included in the study. We excluded patients who presented in pulseless VT, had a known do not resuscitate (DNR) order, and those who had a public access defibrillator applied. Cases where a public access defibrillator was applied were excluded as we could not ensure complete capture of all defibrillation records to verify successive defibrillation attempts were made. Patients who presented in VF but did not have three successive standard defibrillations (terminated VF prior to three shocks) were excluded from the study. We did not include fire defibrillation attempts prior to EMS paramedic defibrillation as not all regional fire services had defibrillator files available to review. The study was approved by the Sunnybrook Health Sciences Centre Research Ethics Board.

Measurement and study definitions

For the purpose of our study, refractory VF was defined as patients who presented in VF, had three successive standard defibrillation attempts and remained in VF at the time of the fourth rhythm analysis. VF termination was defined as the absence of VF at the rhythm check following defibrillation and two minutes of CPR. We chose a pragmatic definition of VF termination that was consistent with the provision of CPR by our paramedics. For the purpose of our study, VF could therefore be terminated into ROSC, pulseless electrical activity (PEA) or asystole.

Using a computerized, structured, data abstraction form, trained research personnel reviewed the ambulance call reports (ACR) and extracted patient data. ACRs for all cases were reviewed to collect data on Utstein variables (patient age, gender, public/private location, EMS witnessed arrest, bystander witnessed arrest and bystander CPR), event characteristics and treatment received (time from 911 call to arrive scene, time from 911 call to first defibrillation delivered, time from 911 call to ROSC, intubation, epinephrine given, total amount of epinephrine given (mg), antiarrhythmic given, and total amount of antiarrhythmic given (mg). Data related to antiarrhythmic use was limited to 2017 as multiple agencies participated in the Resuscitation Outcomes Consortium Amiodarone vs Lidocaine vs Placebo (ALPS) trial for shock refractory VF during 2015–2016, therefore, the exact antiarrhythmic drug (or placebo) could not be confirmed.[25]

CPR quality data and defibrillation data from all eligible resuscitations were abstracted from the compression acceleration signal and impedance channel measurements recorded by the defibrillator (Zoll AED Plus, X series defibrillators, Zoll Medical, Chelmsford, Massachusetts, LP 15 Stryker Corporation, Seattle, Washington) and were assessed for chest compression fraction (CCF), compression rate (per minute), and compression depth (mm) when available. Pre- and post-shock times were abstracted for standard and DSED attempts (when available). The total number of defibrillations delivered was abstracted from both the defibrillator files and the ACR. If any discrepancy existed for the number of defibrillation attempts delivered, data from the defibrillation file was used. Similarly, determination of VF termination and VF termination into ROSC was made through use of both the defibrillator file and the ACR. If any discrepancy existed in the determination of either outcome, the interpretation from the defibrillation file was used. Data for all defibrillations during each resuscitation were abstracted up to the point of first ROSC or transfer of care at the receiving ED. We excluded cases of delayed ROSC in which VF termination resulted in asystole or pulseless electrical activity (PEA), which subsequently received ongoing resuscitation (CPR, antiarrhythmic, epinephrine) and eventually obtained ROSC as we felt this outcome was unrelated to the mode of defibrillation provided. ROSC was defined as the restoration of a spontaneous rhythm noted on the defibrillator files with a corresponding palpable pulse noted on the paramedic ambulance call report and was included when occurring in the rhythm analysis 2 min after a defibrillation attempt (standard or DSED) was provided.

Statistical analyses

Descriptive statistics were summarized using means and standard deviations (SD), medians with interquartile range (IQR), where appropriate. The Pearson chi-square test was used to compare the proportion of patients who terminated VF and those who terminated VF to ROSC between those receiving only standard defibrillation and those receiving at least one DSED attempt. Risk ratios (RR) were computed such that a value more than 1 indicated that DSED was better than standard defibrillation and statistical significance was defined as 95% CI of the RR that excluded unity. All statistical analyses were two-tailed with an alpha of 5% and performed using IBM SPSS Statistics, version 25 (IBM, Armonk, NY, USA).

Results

During the study period, 252 patients met inclusion criteria. Of the 252 patients included in the analysis, 201 (79.8%) received standard defibrillation and 51 (20.2%) patients received DSED. Descriptive characteristics are noted in Table 1. Age, sex, location of arrest, EMS witnessed arrest, bystander witnessed status and rate of bystander CPR were similar between standard and DSED groups.

Table 2 depicts the CPR quality provided by paramedics during the resuscitations. With respect to CCF, compression rate, pre- and post-shock pause and compression depth, CPR quality was compliant with the current guidelines[26,27] with no significant differences detected between groups.

Resuscitation characteristics and treatment provided are described in Table 3. The groups were similar with respect to system response times and treatment characteristics. Time to ROSC was longer in the DSED group, consistent with delayed application of the intervention. Endotracheal intubation was just over 50% in both groups. The majority of cases (>90% for epinephrine and >80% for amiodarone) in both groups received epinephrine and amiodarone, with a mean (SD) dose of epinephrine of 4.5 (2.1) mg for those receiving standard defibrillation, compared to 5.3 (1.9) mg in the DSED group.

To assess the relationship between number of defibrillation attempts, mode of defibrillation (standard vs DSED) and our outcome measures of VF termination and VF termination to ROSC, we constructed Table 4. We first divided our overall cohort into two groups, those who only received standard defibrillation throughout their resuscitation, and those who received at least one DSED as part of their resuscitation. To assess the impact of mode of defibrillation on a shock-by-shock basis, we analyzed what type of defibrillation (standard or DSED) was provided to every patient at each defibrillation attempt. This allowed us to account for the variable time at which the

Table 1 – Patient characteristics of study population.

Characteristic	Standard defibrillation n = 201	DSED n = 51
Mean (SD) age (years)	63.8 (15.7)	61.8 (14.3)
Male	170 (84.6%)	43 (84.3%)
Public location	59 (29.4%)	11 (21.6%)
EMS witnessed	5 (2.5%)	2 (3.9%)
Bystander witnessed	109/198 (55.1%)	34/50 (68%)
Bystander CPR	104/196 (53.1%)	25/50 (50%)

DSED = double sequential external defibrillation; EMS = emergency medical service; CPR = cardiopulmonary resuscitation. SD = standard deviation.

initial DSED was provided during each individual resuscitation. For example, at defibrillation attempt number four, 201 patients received standard defibrillation in the standard cohort. Of the 51 patients in the overall DSED cohort, three patients received a DSED at defibrillation number four, while 48 patients received a standard defibrillation resulting in a total of 249 patients who actually received standard defibrillation and three patients who received DSED at defibrillation number four. To determine the number of patients remaining at each subsequent defibrillation attempt, patients were removed from the table once VF was terminated or they did not receive further defibrillation attempts during their resuscitation. For example, if a patient only had five defibrillation attempts in total, they would be removed from the table from defibrillation attempt number six onward. This iterative process was continued until we identified the patients(s) with the maximal number of shocks provided during their resuscitation.

Overall, VF termination was similar between standard and DSED cohort (78.1% vs. 76.5%; RR: 1.0; 95% CI: 0.8–1.2). In our shock-based analysis, when early defibrillation attempts were considered (defibrillation attempt 4–8), VF termination was higher for those receiving DSED compared to standard defibrillation (29.4% vs. 17.5%; RR: 1.7; 95% CI: 1.1–2.6). When late defibrillation attempts were considered (defibrillation attempt 9–17), VF termination was higher for those receiving DSED compared to standard defibrillation (31.2% vs. 17.1%; RR: 1.8; 95% CI: 1.1–3.0). Overall, ROSC was similar between the standard and DSED groups (21.4% vs. 17.6%; RR: 0.8; 95% CI: 0.4–1.6). When early defibrillation attempts were considered (defibrillation attempt 4–8), ROSC was higher for those receiving DSED compared to standard defibrillation (15.7% vs. 5.4%; RR: 2.9; 95% CI: 1.4–5.9). When late defibrillation attempts were considered (defibrillation attempt 9–17), ROSC rates were similar for those receiving DSED compared to standard defibrillation (1.3% vs. 0.8%; RR: 1.6; 95% CI: 0.1–25.2). For cases where DSED terminated VF into ROSC, the median (interquartile range) number of standard defibrillations prior to DSED was 4 (4, 6), compared to 7 (6, 9) defibrillations when DSED did not result in ROSC. When DSED terminated VF into ROSC, it did so with a single DSED in 66.7% of cases. When VF was not terminated into ROSC, it was terminated into asystole (standard 18.4%, DSED 38.5%) and PEA (standard 54.4%, DSED 38.5%).

Discussion

This observational cohort study found similar overall rates of VF termination and VF termination to ROSC when DSED was compared to standard defibrillation for refractory VF during OHCA. However, when comparing the outcomes of interest at each individual defibrillation attempt, DSED was associated with improved outcomes when compared to standard defibrillation between defibrillations four and eight. We did note ongoing VF termination after eight defibrillations (particularly in the DSED cohort), but the outcome of ROSC was rare after eight defibrillations regardless of the type of defibrillation provided. The finding of improved VF termination to ROSC with fewer preceding standard shocks suggests that successful resuscitation with DSED may be a time dependent variable with greater success early in the resuscitation.

The reason ongoing defibrillations may fail during resuscitation from VF is believed to be at least twofold. As VF persists, the energy required to defibrillate increases as a function of time, due to ischemia induced changes in conduction velocity and refractoriness. Second, if the initial defibrillations fail to terminate VF, the energy supplied to the fibrillating heart may be insufficient to terminate VF. Finally, as resuscitation progresses, ongoing hypoxia, acidosis and exogenous and endogenous catecholamine surges increase myocardial oxygen consumption, making the ventricle more difficult to successfully defibrillate.[9–12]

Our study findings are similar to previously published case series. Cabanas et al.[17] were able to demonstrate similar rates of VF termination (70%) as noted in our study (76.5% VF termination in cases receiving at least one DSED), although the definition of refractory VF differed significantly (inclusion of non-VF presenting rhythms and requirement of five standard defibrillations prior to DSED). For the purpose of our study, refractory VF was defined as OHCA patients who presented in VF, had three successive defibrillation attempts and remained in VF at the fourth rhythm analysis. In a retrospective analysis of 50 DSED cases over a

Table 2 – CPR quality metrics.

CPR quality metric	Standard defibrillation n = 201	DSED n = 51
Mean (SD) compression rate/min	109.6 (8.9)	111.5 (7.3)
Mean (SD) compression depth (cm)	5.7 (1.0)	5.8 (0.9)
Mean (SD) chest compression fraction (%)	83.0 (11.6)	84.2 (5.7)
Median (IQR) pre-shock pause (secs)[a]	6.5 (2, 12.6)	4.3 (1.7, 9.5)
Median (IQR) post-shock pause (secs)	4.7 (3.4, 6.0)	4 (3, 5.5)
Median (IQR) pre-shock pause (secs) DSED shocks	N/A	3.5 (1.5, 14.1)

CPR = cardiopulmonary resuscitation; DSED = double sequential external defibrillation; SD = standard deviation; IQR = interquartile range.
[a] Shock pause data shown for first three standard defibrillations in both standard and DSED cohorts.

Table 3 – Event characteristics and treatment received on scene.

Characteristic	Standard defibrillation n = 201	DSED n = 51
Mean (SD) time interval from 911 call to first vehicle on scene[a]	7.1 (2.8) min	7.1 (2.9) min
Mean (SD) time interval from 911 call to first shock delivered	11.9 (4.8) min	11.6 (4.1) min
Mean (SD) time interval from scene arrival to first ROSC	18.6 (6.7) min	23.3 (10.8) min
Intubation (ETT)	109/197 (55.3%)	28 (54.9%)
Epinephrine given	184/197 (93.4%)	50 (98.0%)
Mean (SD) dose of epinephrine given	4.5 (2.1) mg	5.3 (1.9) mg
Amiodarone given	51/62 (82.3%)	28/30 (93.3%)
Mean (SD) dose of amiodarone given	393.6 (80.1) mg	427.2 (54.5) mg

DSED = double sequential external defibrillation; SD = standard deviation; ROSC = return of spontaneous circulation; ETT = endotracheal intubation.
[a] Response time intervals reflect the time from dispatch notification to arrival of the paramedic vehicle at scene.

Table 4 – The proportion of patients who terminated ventricular fibrillation and those who terminated VF to ROSC by defibrillation number and type.

	Standard defibrillation only			Patients with at least one DSED			
Defibrillatio mumber	n	VF termination n (%)	ROSC n (%)	n	VF termination n (%)	Number of DSED attempts to VF termination	ROSC n (%)
4	249	48 (19.3%)	14 (5.6%)	3	1 (33.3%)	1[a]	1 (33.3%)
5	190	29 (15.3%)	14 (7.4%)	9	3 (33.3%)	1[a], 1[a], 1[a]	3 (33.3%)
6	155	26 (16.8%)	10 (6.4%)	7	4 (57.2%)	1, 2[a], 2, 2	1 (14.3%)
7	111	22 (19.8%)	2 (1.8%)	14	4 (28.6%)	1[a], 1, 1, 3[a]	2 (14.3%)
8	74	11 (14.9%)	2 (2.7%)	18	3 (16.7%)	1[a], 1, 1,	1 (5.6%)
9	50	15 (30.0%)	0 (0.0%)	21	6 (28.6%)	1, 1, 1, 3, 3, 5	0 (0.0%)
10	28	2 (7.1%)	1 (3.6%)	16	3 (18.8%)	2, 2, 2	0 (0.0%)
11	18	0 (0.0%)	0 (0.0%)	15	6 (40.0%)	1, 2, 2, 3, 4, 5	0 (0.0%)
12	11	1 (9.1%)	0 (0.0%)	11	4 (36.4%)	2, 2, 3, 6	0 (0.0%)
13	8	2 (25.0%)	0 (0.0%)	6	3 (50.0%)	1, 2, 7[a]	1 (16.7%)
14	4	1 (25.0%)	0 (0.0%)	5	1 (20.0%)	3	0 (0.0%)
15	2	0 (0.0%)	0 (0.0%)	1	1 (100.0%)	2	0 (0.0%)
16	1	0 (0.0%)	0 (0.0%)	1	0 (0.0%)		0 (0.0%)
17	1	0 (0.0%)	0 (0.0%)	1	0 (0.0%)		0 (0.0%)

VF = ventricular fibrillation; ROSC = return of spontaneous circulation; DSED = double sequential external defibrillation.
[a] Shock terminated VF into ROSC.

three-year time frame, Ross et al., reported no improvement in the primary outcome of neurologically intact survival with DSED, but did not include data regarding the timing of the DSED shock, the presenting rhythm of included patients, or CPR quality metrics.[18] Conversely, in a small case series employing a protocol similar to our cohort, Merlin et al., reported that 43% of DSED cases survived to hospital admission and 28.6% had neurologically intact survival.[28]

Although DSED is being performed in multiple EMS agencies around the world, there is a paucity of evidence to support its use. At best, the science to date is hypothesis-generating. As noted by Pourmand et al., "although preliminary research suggests DSED may be successful in treating refractory VF, a well-designed, high quality randomized trial is necessary to elucidate the efficacy and role of DSED for the treatment of refractory VF."[29] Our research team is currently enrolling patients in a cluster randomized controlled trial to assess the impact of alternate defibrillation strategies (vector change defibrillation involving changing pad placement from anterior–anterior to anterior–posterior and DSED compared to standard defibrillation) applied early (after the first three successive failed shocks) for patients presenting in refractory VF (https://clinicaltrials.gov/ct2/show/NCT03249948).

This observational study has several limitations. Our findings are descriptive and therefore no causal association can be inferred between DSED and our study outcomes. A randomized controlled trial would be of benefit in further assessing this relationship. We chose a pragmatic definition of VF termination that differs from previous definitions of VF (VF termination within five seconds of defibrillatory shock.)[30] This historical definition dates back to 2005, prior to multiple changes in the provision of CPR. Recent focus on high quality CPR has resulted in extremely short post-shock pauses for the EMS agencies included in this study. Additionally, CPR artifact introduced into the defibrillator monitor and defibrillator files made the use of this historical definition problematic due to CPR induced artifact noted in defibrillator files. We acknowledge that refractory VF has no single consistent definition. Our definition of refractory VF (presentation in VF followed by three successive failed defibrillations and remain in VF at the fourth rhythm analysis) was based on the premise that if VF remains following three standard defibrillations, the probability that subsequent defibrillation will result in VF termination decreases over time. This is consistent with data from a Swedish cardiac arrest registry, where Holmen et al.[5] demonstrated a progressive

decrease in both ROSC and survival with increasing defibrillation number for patients presenting in VF. Our study did not report patient important outcomes such as survival to hospital discharge or neurologically intact survival as we would have been underpowered to report such outcomes. Our study findings may have been subject to selection bias as the use of DSED was at the discretion of the paramedic and online medical control as opposed to a protocolized consistent application of DSED at a specific point in the resuscitation. Although defibrillator files were available for the vast majority of cases in which DSED was employed we cannot calculate with confidence the time interval between the DSED shocks which would require precise synchronization of time on both defibrillators used which is known to be extremely challenging in prehospital care.[31] Finally, our use of DSED did require paramedics to seek online medical control prior to providing DSED. This process likely increased the time to eventual DSED.

Conclusions

Our observational findings suggest that while overall VF termination and ROSC are similar between standard defibrillation and DSED, earlier DSED may be associated with improved rates of VF termination and ROSC compared to standard defibrillation for refractory VF. A randomized controlled trial is required to assess the impact of early application of DSED on patient-important outcomes.

Conflict of interest statement

Dr. Cheskes has received speaking honorarium for educational events on CPR quality from Zoll Medical and Stryker Corporation. Dr. Cheskes has received grant funding from the Laerdal Foundation for the DOSE VF RCT. Dr. Morrison is the Robert and Dorothy Pitts Chair in Acute Care and Emergency Medicine funded by St. Michael's Foundation and the University of Toronto for which she receives salary support.

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