American Journal of Medical Case Reports, 2019, Vol. 7, No. 12, 325-328
Available online at http://pubs.sciepub.com/ajmcr/7/12/6
Published by Science and Education Publishing
DOI:10.12691/ajmcr-7-12-6

Beyond the Limit: Double Sequential Defibrillation as an Alternative Therapy for Refractory Ventricular Fibrillation

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Received August 06, 2019; Revised September 12, 2019; Accepted September 23, 2019

Abstract The incidence of out-of-hospital cardiac arrest (OHCA) reported from the Resuscitation Outcomes Consortium (ROC) and the CARES registry in 2016 suggests that 110.8 individuals per 100,000 population or 347,000 adults annually suffer from OHCA in the United States (US); likewise, the incidence of in-hospital cardiac arrest (IHCA) reported by Get With The Guidelines-Resuscitation (GWTG-R) suggests that each year, 209,000 people are treated for IHCA. Double sequential defibrillation (DSD) has been proposed as an alternative treatment for refractory ventricular fibrillation (VF) as there appears to be a trend of promising outcomes, including termination of refractory VF, sustained ROSC, increased short term survival and favorable outcomes to hospital discharge. We report a case of prolonged resuscitation of an 72-year-old man who developed pulseless ventricular tachycardia (pVT) that progressed to refractory VF terminated by DSD. In addition, we provide a quick reference that summarizes the characteristics and resuscitative parameters of the reported case.

Keywords: *cardiac arrest, double sequential defibrillation, in-hospital cardiac arrest, out-of-hospital cardiac arrest, refractory ventricular fibrillation, resuscitation*

Cite This Article: Dennis Miraglia, Lourdes A. Miguel, and Wilfredo Alonso, "Beyond the Limit: Double Sequential Defibrillation as an Alternative Therapy for Refractory Ventricular Fibrillation." *American Journal of Medical Case Reports*, vol. 7, no. 12 (2019): 325-328. doi: 10.12691/ajmcr-7-12-6.

1. Introduction

Despite significant advances in resuscitative medicine in recent decades, out-of-hospital cardiac arrest (OHCA) remains a leading cause of death, accounting for up to 1 death per 1,000 population worldwide. The incidence of OHCA reported from the Resuscitation Outcomes Consortium (ROC) and the Cardiac Arrest Registry to Enhance Survival (CARES), in 2016, suggests that 110.8 individuals per 100,000 population, or 356,500 people of any age or 347,000 adults annually suffer from emergency medical services (EMS) assessed OHCA in the United States (US) [1,2]. Likewise, the incidence of in-hospital cardiac arrest (IHCA) reported by Get With The Guidelines-Resuscitation (GWTG-R) suggests that each year, 209,000 people are treated for IHCA [3]. Cardiopulmonary resuscitation (CPR) and early defibrillation are the most effective treatment for cardiac arrest patients, who present, shockable rhythms of ventricular fibrillation/pulseless ventricular tachycardia (VF/pVT) [4,5,6]. However, there is a subgroup of patients in which VF remains refractory to standard defibrillation (SD). Refractory VF is a life-threatening arrhythmia unresponsive to at least three SD attempts and antiarrhythmic medications; although, no consensus exists as to a definition of refractory VF in the literature [7]. Mortality rates in patients with refractory VF are high, perhaps because resuscitation lasts longer than 20 minutes and the occurrence of ischemic burden and progressive myocardial dysfunction imposed during resuscitation is significantly higher in these patients [5,8,25,27]. There are currently no firm guidelines regarding the treatment of refractory VF. Double sequential defibrillation (DSD) is an approach that has been proposed as an alternative treatment for refractory VF as there appears to be a trend of promising outcomes, including termination of refractory VF, sustained ROSC, increased short term survival and favorable outcomes to hospital discharge [9-24]. We report a case of prolonged resuscitation of an 72-year-old man who developed pulseless ventricular tachycardia (pVT) that progressed to refractory VF terminated by DSD. In addition, we provide a quick reference that summarizes the characteristics and resuscitative parameters of the reported case.

2. Case Presentation

An 72-year-old man with a past medical history of hyperlipidemia, hypertension, coronary artery disease

(CAD) and heart failure (HF) was brought to the emergency department by ambulance with a chief complaint of shortness of breath (SOB) of approximately 2 days of evolution and had progressively worsened, associated with mild substernal chest discomfort. Vital signs included a temperature of 36.8°C, a pulse rate of 89 beats/min, a respiratory rate of 16 breaths/min, oxygen saturation of 96% on pulse oximetry, a blood pressure of 154/90 mmHg and a mean arterial pressure (MAP) of 111 mmHg. Physical examination revealed jugular venous distention (JVD) and 2+ pitting bilateral lower extremity edema. His initial lab results showed a pro-B-type natriuretic peptide (NT-proBNP) level of 2102 pg/mL, a troponin T (cTnT) level of 0.034 ng/mL, and an unremarkable comprehensive metabolic panel (CMP). His chest x-ray (CXR) revealed cardiomegaly, interstitial pulmonary infiltrates suggestive of pulmonary congestion and an atheromatous and tortuous thoracic aorta characteristic of chronic atherosclerotic disease. The initial 12-lead electrocardiogram (ECG) obtained at the emergency department revealed a normal sinus rhythm at 84 beats/min, PR interval of 189 ms, QRS duration of 108 ms, slight QT prolongation (QTc, 472 ms), nonspecific ST-T-wave changes, and devious signs of right atrial overload (wide variability in QRS amplitude between V1 and V2). The patient was admitted to the hospital under internal medicine for the management of acute exacerbation of congestive heart failure (CHF). The calculated GWTG-HF risk score at admission was 34 points, for up to 5% predicted in-hospital all-cause mortality. As part of the admission work-up, transthoracic echocardiography (TTE) was ordered and the result was consistent with a grade III diastolic dysfunction. The TTE revealed moderate concentric left ventricular hypertrophy (IVSd 1.5cm), severe global hypokinesis of the left ventricle and reduce myocardial contractility (dP/dt 708.6 mmHg/s). The calculated left ventricular ejection fraction (LVEF) was 21%. The second day of admission the patient's shortness of breath and arterial blood gases (ABGs) did not improve and bilevel positive airway pressure (BiPAP) therapy was initiated as his condition deteriorated. He was transferred to the intensive care unit (ICU). The fourth day of admission he developed pVT. He was immediately defibrillated at 200 J. The counter-shock was not successful, and his rhythm progressed to VF. The Advanced Cardiac Life Support (ACLS) algorithm was followed for VF. He received several doses of IV epinephrine, two doses of IV amiodarone (300 mg and then 150 mg) and 8 unsuccessful conventional defibrillations at 200 J. After 36 minutes of resuscitation the patient continued in refractory VF and, subsequently, the decision was made to attempt DSD. Conversion of the refractory VF was successfully achieved after the second DSD attempts; however, ROSC was maintained for less than 20 minutes before the patient when into asystole. Unfortunately, despite subsequent management, there was no improvement, ultimately no ROSC was achieved, and CPR was stopped. The decision to continue CPR beyond 30 minutes in this patient was based on the refractory nature of the dysthymia and the disposal of many medical personnel to sustain CPR. Table 1 summarizes the characteristics and resuscitative parameters of the reported case.

Table 1. Characteristics and resuscitative parameters of the reported case.

Variables	n = 1
Age	72 years
Gender	Male
Risk factor	HTN, CAD, HF
Witnessed	Yes
Time to cardiopulmonary resuscitation	≤ 2 min
In-hospital cardiopulmonary resuscitation	Yes
Initial rhythm	pVT
Biphasic standard defibrillation shocks (200 J)	8
Time to standard defibrillation shocks	< 4 min
DSD pads placement	Anterior-lateral
Type of shock	Double sequential
Biphasic DSD shocks (400 J)	2
Time to DSD	36 min
Ventricular fibrillation terminated	Yes
Return of spontaneous circulation	Yes
Resuscitation time	38 min
24-hour survival	No
CPC post-cardiac arrest	5
CPC at the time of discharge	Not applicable

CAD = coronary artery disease.
CPC = cerebral performance category.
DSD = double sequential defibrillation.
HF = heart failure.
HTN = hypertension.
pVT = pulseless ventricular tachycardia.

3. Discussion

Several case reports and case series have been published in recent years supporting the use of DSD as an alternative treatment for refractory VF as there appears to be a trend of promising outcomes [10-12,16-24]. Coronary artery disease (CAD) is the most common reversible cause in patients with VF/pVT OHCA [25]. Patients resuscitated from VF/pVT cardiac arrest have significant coronary stenosis in up to 50% of cases. Although, there is a spectrum of possible causes and risk factors that could had triggered the cardiac arrest in this patient, myocardial ischemia remains the most likely etiology. The outcomes of this case suggest the DSD may be of benefit in terminating refractory VF and achieving temporary or sustained ROSC, but the benefit of achieving temporary or sustained ROSC in refractory VF should be weighed against ischemic burden and progressive myocardial dysfunction imposed during resuscitation [26,27]. Our case is similar to previously described cases in which the patients have remained in refractory VF to multiple SD shocks before receiving DSD [10-24]. Likewise, we find similarities between the outcome in this case and the results described by Cabañas et al. on the first case series published on DSD in OHCA. The mean of DSD shocks was 2.7 ± 2.2 with a time average to DSD of 36.8 min ± 8.5. Overall, refractory VF was terminated in 7 out 10 patients; in those who were terminated (70 %), ROSC was achieved only in 30.0% of them; in the end there were no survival to hospital discharges [10]. Recent studies support that the use of early DSD may terminate refractory VF and maintain sustained ROSC to hospital admission, but no increased benefit in survival or good neurological outcome (CPC 1 and 2) at the time of discharge when compared with the best current standard of care [13,14,15]. The first large study on DSD in OHCA was published in 2016 by Ross et al. This observational retrospective case-control study evaluated neurologically intact survival to discharge as a primary outcome in 50 patients who received DSD vs. 299 who received biphasic SD at 200 J; not statistically significant (p = 0.32) was found between the two groups. Ultimately, the study did not find statistically significant (p = 0.34) in survival rates to hospital discharge between the DSD group vs. the SD group [13]. The following year, an OHCA observational retrospective cohort study by Emmerson et al. evaluated the data from 45 patients treated with DSD vs. 175 patients who received SD. The authors found that 22.2% of the patients obtained a pre-hospital ROSC and 7% survived to hospital discharge in the DSD group; however, the researchers identified no clear benefit of the use of DSD to treat refractory VF vs. the SD group [14]. Lastly, in 2019, another retrospective study on DSD in OHCA was published by Caheskes et al. While the study did not evaluate survival or functional outcomes to hospital discharge, it did find that there is an association between improved rates of refractory VF termination and ROSC, when early DSD was considered for refractory VF (defibrillation attempt 4-8) in the DSD group vs. the SD group (15.7% vs. 5.4%; RR: 2.9; 95% CI: 1.4-5.9). Nevertheless, when the overall effect of early and late defibrillation attempts where combined, VF termination and ROSC were similar amongst the DSD group vs. the SD group (17.6% vs. 21.4%; RR: 0.8; 95% CI: 0.4-1.6) [15]. DSD is not currently included in AHA 2017 guidelines for the management of patients with ventricular arrhythmias (VA) nor specific recommendations have been established for the treatment of refractory VF [28]. In the meantime, it is necessary to agree upon a uniform definition and a standardized protocol that can be implemented at large scale to treat refractory VF.

4. Conclusion

There is a dearth of available data and no enough evidence concerning the use of DSD for the management of IHCA and OHCA refractory VF. Although most of the existing literature on DSD for refractory VF has been associated with improved rates of VF termination and ROSC, increased long-term survival (6-12 months) and functionally favorable survival rates to hospital discharge are not well characterized. We would like to suggest that early use of DSD (defibrillation attempt immediately after the 3rd shock) may have potential benefit in termination of refractory VF and sustained ROSC to hospital admission from OHCA on the basis of available evidence. Additional studies are necessary to determine the efficacy and safety of DSD for the treatment of refractory VF.

Conflict of Interest Statement

None of the authors have any relevant conflicts of interest to disclose.

Funding

The authors received no funding for this work.

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