Double Sequential Defibrillation

Erica M. Simon, DO, MHA[a], Kaori Tanaka, DO, MSPH[b,*]

KEYWORDS

• Double sequential defibrillation • Defibrillation • Refractory ventricular fibrillation • Vector theory • Threshold theory

KEY POINTS

- Refractory ventricular fibrillation is rare, occurring in 0.5 to 0.6 per 100,000 individuals.
- The mortality associated with refractory VF ranges from 85% to 97%.
- Current studies have demonstrated no statistically significant benefit of DSED, as compared with standard therapy, in terms of survival to hospital discharge and neurologic outcomes.

INTRODUCTION

Each year more than 300,000 out-of-hospital cardiac arrests (OHCA) occur in the United States.[1] In the setting of ventricular fibrillation (VF), the most frequently encountered tachyarrhythmia following spontaneous cardiac arrest, early defibrillation is paramount.[2,3] Today, communities equipped with mechanisms to ensure early defibrillation report mortality secondary to OHCA as 15% to 40%.[4–7] Although there is a clear benefit to the delivery of electricity during VF, the treatment of patients experiencing VF refractory to defibrillation remains a clinical concern.

REFRACTORY VENTRICULAR FIBRILLATION

Although there is no universal definition of refractory VF, it is generally considered to exist following three to five unsuccessful defibrillation attempts during adequate cardiopulmonary resuscitation.[8–11] Refractory VF is rare, with an estimated incidence of 0.5 to 0.6 episodes per 100,000 persons.[12] Individuals who experience refractory VF frequently have underlying structural heart disease and renal disease.[13–15] Additional risk factors for the development of refractory VF include advanced age, male sex, and reduced left ventricular ejection fraction.[13,14] Although interventions in the field may be limited, important precipitants for consideration include hypokalemia and hypomagnesemia.[14,16] Current studies estimate the mortality of refractory VF as 85% to 97%.[17,18] Although amiodarone and lidocaine represent the standard of care for the management of shock-refractory VF,[19] emergency medical services literature has placed an increasing focus on the potential role of prehospital double sequential defibrillation (DSED).

DOUBLE SEQUENTIAL DEFIBRILLATION

In the mid-1980s, electrophysiologists began the work of assessing methods of defibrillator shock delivery in canines.[20–22] Although research findings were variable among study groups, several investigators observed sequential shocks as reducing the total energy required to achieve successful defibrillation (laying the groundwork for the threshold theory: the first defibrillation lowers

Disclosure: The authors have nothing to disclose.
[a] Department of Emergency Medicine, San Antonio Uniformed Services Health Education Consortium, 3551 Roger Brooke Drive, Fort Sam Houston, TX 78234, USA; [b] Department of Emergency Medicine, University of Texas Health San Antonio, 7703 Floyd Curl Drive, MC 7736, San Antonio, TX 78229, USA
* Corresponding author.
E-mail address: tanakak@uthscsa.edu

Cardiol Clin 36 (2018) 387–393
https://doi.org/10.1016/j.ccl.2018.03.006

the threshold of success for the second defibrillation), and that the application of an additional electrode (a second vector), as increasing the likelihood of successful rhythm conversion (vector theory).[20,21] As applied to human models, proponents of the threshold and vector theories hypothesize that multiple shocks achieve a greater intracardiac current flow in the myocardium, thereby terminating VF, and that the application of an additional vector increases myocyte response, because cardiac fibers display directional sensitivity to electrical fields.[22–24] Today these mechanisms of action continue to be debated as some attribute the success of DSED to increased energy delivery (appropriate weight-based therapy).[25]

RESEARCH IN HUMAN SUBJECTS

In 1994, Hoch and colleagues[25] published the first human data regarding DSED.[25] In a randomized, controlled trial, the investigator and his colleagues demonstrated the safety and efficacy of sequential pulse shocks in the termination of refractory VF in five patients undergoing cardiac ablation. Since this time, DSED studies that require mention include those performed by Emmerson and colleagues,[26] Ross and colleagues,[29] Cabanas and colleagues,[11] Cortez and colleagues,[10] and Merlin and colleagues.[9] **Table 1** offers a summary of DSED literature.

In 2017, Emmerson and colleagues[26] published a retrospective observational analysis of patients who received DSED, performed by advanced paramedics of the London Ambulance Service. Of the 45 individuals experiencing refractory VF (42 males), return of spontaneous circulation (ROSC) was obtained in 17 following 2.5 ± 1.9 DSEDs (10 sustained ROSC until hospital arrival, DSED was performed following 10.2 ± 5.2 standard shocks, three survived to hospital discharge).[26] As compared with individuals receiving standard therapy (>6 standard shocks without DSED), no statistically significant differences in outcomes were observed (n = 175; mean age, 62.5 ± 16.5; 144 males; mean 10.4 ± 3.7 standard shocks; 11 survived to hospital discharge).[26] Mean time from dispatch to first defibrillation was 11:32 ± 5:37 for the DSED group and 12:22 ± 4:50 for the standard therapy group.[26]

Ross and colleagues,[29] in their performance of a retrospective cohort analysis, compared the neurologic outcomes of patients with presumed refractory or recurrent VF, treated in the prehospital setting with DSED (n = 50), with those who received standard therapy (single shocks; n = 229). The authors' study revealed no statistically significant difference in cerebral performance categories (CPC) at hospital discharge. A total of 6% in the DSED group and 11.4% in the standard therapy group had CPC 1 or 2 at discharge (P = .317; odds ratio [OR], 0.50; 95% confidence interval [CI], 0.15–1.72).[29] Secondary outcomes of ROSC by EMS 28% versus 37.6% (P = .255; OR, 0.65; 95% CI, 0.33–1.27), survival to hospital admission 32% versus 35.4% (P = .744; OR, 0.86; 95% CI, 0.45–1.65), and survival to hospital discharge 8% versus 14.4% (P = .356; OR, 0.52; 95% CI, 0.17–1.53) also lacked statistical significance.[29] Subgroup analysis of patients with refractory VF (n = 26; defined as persisting in VF throughout the resuscitation) again noted no statistically significant difference in primary and secondary outcomes as compared with individuals having received standard therapy.[29]

Cabanas and colleagues,[11] reporting the first case series of DSED used in OHCA, identified a 70% termination of refractory VF following DSED in the prehospital setting (n = 10). Median age was 76.5 years (interquartile range [IQR], 65–82); median resuscitation time was 51 minutes (IQR, 45–62). However, ROSC was achieved in only three individuals, and none survived to hospital discharge.

In contrast to these studies, Cortez and colleagues[10] and Merlin and colleagues[9] offer evidence to suggest the potential for improved outcomes following DSED. Using data from the Columbus Division of Fire, Cortez and his colleagues conducted a retrospective review of patients who had received DSED in the prehospital setting from August 2010 to June 2014.[10] Of the 12 individuals included in the study, ROSC was achieved in three, and all three survived to hospital discharge (two with a CPC of 1, and one with a CPC of 3. Median prehospital resuscitation time was 31.5 minutes (IQR, 24–37.5), median time to DSED was 27 minutes (IQR, 22–33), median single defibrillation attempts were five (IQR, 5–6); and median dual defibrillation attempts were two (IQR, 1–2).[10]

In 2015, Merlin and colleagues[9] published a retrospective case series of patients receiving DSED for presumed refractory VF. Of the seven individuals included in the series, mean age was 62.9 (range, 45–78), mean resuscitation time was 34.3 minutes before first DSED (range, 10–48), mean number of single shocks was 5.4 before DSED (range, 3–9), a mean of two DSED shocks was delivered, VF was converted in five cases, and three individuals survived to hospital discharge with minimal neurologic impairment (CPC 1 or 2).[9]