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Clinical paper

A survey of the incidence of defibrillator damage during double sequential external defibrillation for refractory ventricular fibrillation

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Abstract

Background: Double Sequential External Defibrillation (DSED) is a proposed treatment strategy for patients in refractory VF (RVF) during out-of-hospital cardiac arrest (OHCA). Defibrillator damage employing DSED is a theoretical concern expressed by defibrillator manufacturers yet the incidence of damage during resuscitation remains unknown.

Objective: We sought to explore the incidence of defibrillator damage employing DSED for RVF during OHCA.

Methods: We conducted a survey of EMS agencies, authors of previous publications, EMS medical directors, base hospital medical oversight groups, and defibrillator manufacturers to assess the incidence of defibrillator damage during DSED. Our survey focused on the frequency of DSED use, number of shocks used during DSED, technique used to employ DSED (simultaneous or sequential), and the incidence of defibrillator damage during DSED. We specifically targeted groups that were known to be using DSED in clinical practice.

Results: Our survey response rate was 50% (65/129): 61% (34/56) EMS medical directors, 60% (6/10) authors, 100% (8/8) base hospitals, 33% (1/3) defibrillator manufacturers, 31% (16/52) paramedic services. In our case-based analysis the overall incidence of defibrillator damage was 0.4%. The incidence of defibrillator damage based on total number of DSED shocks was estimated between 0.11% and 0.22%. All reported cases of defibrillator damage occurred using a simultaneous defibrillation technique.

Conclusion: When DSED is employed using either a sequential or simultaneous technique the rate of defibrillator damage appears to be exceedingly low. Further high-quality evidence is required to determine the impact of DSED on patient centered outcomes, but the incidence of defibrillator damage should not limit it use. Defibrillator damage should continue to be monitored in future trials and clinical practice.

Keywords: Refractory Ventricular Fibrillation, Double sequential external Defibrillation, Defibrillator Damage, Out-of-Hospital Cardiac Arrest

Introduction

Double sequential external defibrillation (DSED) has been proposed as a potential therapeutic intervention for patients presenting in refractory ventricular fibrillation (RVF) in out-of-hospital cardiac arrest (OHCA).[1–3] The technique involves the simultaneous or rapid sequential delivery of shocks from two separate defibrillators whose pads are applied in different configurations (generally pads in the anterior-lateral position and anterior-posterior position). The use of DSED is currently not supported in either the 2020 American Heart Association Guidelines or the International Liaison Committee on Resuscitation Consensus on Science although the evidence reviewed by both bodies was considered to be of low quality.[4–5] A current ongoing randomized controlled trial, the Double Sequential External Defibrillation for Refractory Ventricular Fibrillation (DOSE VF NCT04080986) will provide the first high quality evidence as to the potential for DSED to have an impact on clinically relevant patient outcomes.[6] Regardless of the recommendations of the scientific bodies and the ongoing RCT, many agencies have implemented DSED for patients in RVF during OHCA.

One concern of using DSED is the potential to cause defibrillator damage to one of the two defibrillators used in the intervention. Gerstein et al. describe a case of defibrillator damage employing a technique similar to DSED but in a different scenario then refractory ventricular fibrillation.[7] In the case described, simultaneous shocks

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were delivered to perform a synchronized cardioversion in a conscious patient presenting in wide complex tachycardia employing two defibrillators by two different manufacturers (Zoll M series CCT defibrillator and Physio-Control LP 15 defibrillator). Damage was noted by the defibrillator manufacturer to be caused by a "shortage of a high-voltage component of the Therapy PCB, or printed circuit board assembly". The defibrillator manufacturer noted in their review that the defibrillator warranty provided would not cover the "off label use" of the defibrillator for techniques such as DSED. While of interest, it is clear that the application of dual shocks in the manner described is distinct from the use of DSED described in the literature for RVF in OHCA. What remains unclear is the incidence of defibrillator damage when DSED is used during RVF in current practice during OHCA. We therefore sought to explore the incidence of defibrillator damage employing the technique of DSED (either sequential or simultaneous) when employed by emergency medical services (EMS) for RVF during OHCA.

Methods

Study design

We conducted a survey of prehospital organizations and personnel with a high likelihood of DSED use within their EMS system as a result of previous research in the topic area or a known history of DSED use in the EMS agency. Individuals within each organization were invited to participate by email and surveys were completed using Google Forms®. As there was no patient or organization information collected this study met the criteria for exemption from Research Ethics Board review.

Participants

We distributed email invitations to prehospital organizations in both the United States and the province of Ontario, Canada. It was felt that these organizations represented broad coverage of EMS agencies and had a high likelihood of DSED cases within their systems based on previous reported use or publications in the area of interest.

In the United States the survey was distributed to Medical Directors who were members of the EAGLES organization.[8] The EAGLES is comprised of Medical Directors from across the United States (U.S.) covering 50 of the largest cities and approximately-one-third the U.S. population.[8,9].

In Ontario, the survey was distributed to base hospital organizations. Base hospitals are responsible for direct medical oversight and delegation to all paramedics in Ontario. There are eight base hospitals in Ontario that cover the entire province.[9]

In order to ensure that there were not cases that did not get reported to the base hospitals we also sent a secondary email to paramedic services within Ontario. There are 52 distinct paramedic services within the province. Unauthorized use of DSED is not permitted outside of the ongoing clinical trial in the province and so we felt that it is unlikely that there were additional cases of DSED that were not captured by the base hospital medical oversight groups.

Finally, we emailed authors of published literature on DSED to ask about any known defibrillator damage that they were aware of as part of their published research and the three major prehospital defibrillator manufacturers (Zoll Medical, Chelmsford, Massachusetts, Phillips Canada, Markham, Ontario, Stryker Corporation, Seattle, Washington).

Survey

The survey was a brief online questionnaire created using Google Forms®. The survey was emailed to individual participants along with a letter explaining its purpose. The survey was designed to determine the number of uses of DSED, along with any reported damage that had occurred, how the damage had been discovered, and what technique (simultaneous vs sequential) of DSED had been used. There was no prescribed method for determining the number of cases, this was left up to the individuals responding to the survey to get the most accurate number of cases. A single follow-up reminder email was sent to individuals who had not responded three weeks after the initial request. A copy of the surveys is included in Appendix A. We did not define what was meant by defibrillator damage and was left up to the discretion of the respondent as to whether there was damage that had been found. We did collect information on what the damage was and how it was identified.

Analysis

The obtained survey responses were tabulated and reported as descriptive summaries including median (interquartile range) and count (percentages). We were primarily interested in the number of cases of reported defibrillator damage. Using the results of previous studies of DSED and our ongoing randomized controlled trial (NCT04080986) we were able to estimate the total number of DSED shocks administered based on the number of cases of DSED reported by the survey respondents. This provided a better estimate of the incidence of damage on a per shock basis which is more reflective of clinical practice where most patients will require multiple shocks. From previous research the average number of DSED shocks per case was between two and four.

Results

The survey was distributed to 129 individuals and agencies. Our overall response rate was 65 (50 %). The response rates for each of the specific groups are outlined in Table 1. We found an estimated 1130 uses of DSED for OHCA from the survey respondents. From the total number of cardiac arrests, five cases (0.4 % of cases) of defibrillator damage were identified (Table 2). Two of the cases were identified as the defibrillator stopped working, the other three cases were identified on routine testing post-call. All five cases occurred using simultaneous technique where the two shock buttons are pressed together.

From the 1130 cases we were further able to estimate the total number of DSED shocks that may have occurred. Based on the responses received and the results of previous studies and our ongoing RCT we estimated an average of between 2 and 4 DSED shocks per case. This would result in a total of between 2260 and 4520 total DSED shocks, or a rate of defibrillator damage of 0.11 % to 0.22 % per shock.

Discussion

To our knowledge this is the first study exploring the risk and incidence of defibrillator damage employing DSED in practice for the treatment of cardiac arrest. The strength in our survey was the breadth of respondents including EMS medical directors, base hospitals, paramedic services, first authors of previous publications

Table 1 – Survey respondents.

	Survey Sent n	Respondents n (%)
EAGLES Medical Directors	56	34 (61)
Ontario Base Hospital Groups	8	8 (100)
Ontario Paramedic Services	52	16 (31)
Authors	10	6 (60)
Defibrillator Companies	3	1 (33)
TOTAL	129	65 (50)

Table 2 – Reported cases of defibrillator damage.

	Use of DSED	Approximate number of cases	Number of cases or reported damage
EAGLES Medical Directors	14	654	3
Ontario Base Hospital Groups	3	176	0
Ontario Paramedic Services	6	176	0
Authors	6	476	2
Defibrillator Companies	n/a	n/a	n/a
TOTAL	29	1130*	5

* Cases of Ontario Base Hospital Group and Ontario Paramedic Service are the same. Cases overlap between Authors and Ontario Base Hospital Group.

exploring DSED use in OHCA, and defibrillator manufacturers from both North America and Europe. In particular the high response rate from the EAGLES consortium of medical directors representing some of the largest EMS systems in North America suggest that the technique is not only being used for patients in RVF, but appears to be associated with an exceedingly low risk of defibrillator damage.[8] While this was true regardless of the technique (simultaneous vs sequential) employed, the risk of damage appears to be even lower with sequential defibrillation where we did not identify any cases of defibrillator damage using this technique. Finally, while the rate of defibrillator damage was exceedingly low on a per case basis the number would be even lower on a per shock basis, as most cases have multiple shocks administered, underlying the safety of DSED when employed in clinical practice. The acceptable rate of defibrillator damage from this intervention has not been established. Defining an acceptable rate of equipment damage will need to account for various factors such as any potential survival benefit associated with DSED, any threats to patient and/or provider safety, cost of damaged equipment, and any system-level impact.

There have been multiple theories to explain the potential risk of defibrillator damage during DSED. Pads applied to close to each other may direct the current from one device to the second device.[7] The use of defibrillators made by different manufacturers with differences in defibrillator biphasic waveforms (truncated exponential vs rectilinear) and energies may contribute to the potential for defibrillator damage.[10,11] The most common explanation for potential defibrillator damage that may occur during DSED is the exposure of a capacitor of the first defibrillator to high voltages generated by the second defibrillator during a specific time frame post initial defibrillator shock delivery. This exposure may be due to two defibrillators simultaneously measuring impedance in the same patient and directing energy towards the second defibrillator as opposed to the patient. Similarly, if waveforms from each defibrillator used to perform DSED occur at the exact same time, a similar result could potentially occur. Although there is a theoretical risk of defibrillator damage, the actual occurrence in real life scenarios appears to be exceedingly rare. The likely reason for this is by employing either simultaneous or rapid sequential DSED, it is nearly impossible to provide two shocks truly simultaneously (to the msec.) simply due to human reaction time.[12,13] Although the likelihood of defibrillator damage would be theoretically greater with simultaneous DSED the occurrence based on our survey results appears to be low with either technique. In the case described previously by Gerstein et al. it is more than likely that R wave synchronization by each device (which is not performed during DSED) may have led to electronic communication, in which a disturbance caused by an electromagnetic pulse from one device affects the signal in an adjacent circuit. This may have resulted in misdirection of the applied electric current from one device to the other instead of to the patient. It is important to note that the mechanisms proposed to potentially cause defibrillator damage are theoretical and not based on experimental evidence. This conclusion would seem to be supported by our survey findings.

Although the potential for defibrillator damage has been described, DSED continues to be used in clinical practice despite guidelines established by both the AHA and ILCOR. Recent research suggests that the proposed mechanism of defibrillator damage involving the exposure of one defibrillator to the voltage generated by the second defibrillator may in fact be mitigated by altering the pad position commonly used during DSED. Taylor et al. demonstrated in a pig model of DSED that peak voltage exposure was, on average, 10-fold higher for parallel than orthogonal vectors ($p < 0.0001$) of defibrillation.[14] This finding and the associated improved safety profile appear to be consistent with the findings of Cabanas et al.[15] and Cheskes et al.[6,16] who have consistently employed the orthogonal pad position during DSED and have not reported any cases of defibrillator damage during their research. The orthogonal pad position is also described by the majority of respondents in our survey perhaps further corroborating the safety profile of this pad position. Interestingly, the pad position noted in the previously published case of defibrillator damage was consistent with the parallel pad alignment associated with higher voltage exposure described by Taylor et al.

The findings of our survey must be taken in the context of the shortcomings of any survey assessing the benefit or lack thereof of any intervention. While our survey included a wide array of known and potential individuals and services employing DSED we cannot guarantee that we contacted all DSED users. Our survey response was noted to be high among EMS medical directors and base hospitals but lower among paramedic services likely related to the use of the technique only by services currently involved in the ongoing RCT. While the rate of defibrillator damage was found to be exceedingly low in our study, we cannot say with certainty that all cases of defibrillator damage were reported nor that mechanisms were established to ensure that defibrillator damage did not occur following each application of DSED. Finally, although we contacted all major defibrillator manufacturers as part of our survey, only one manufacturer responded confirming they had no reported cases of defibrillator damage employing DSED using their defibrillators.

Conclusion

When DSED is employed using either a sequential or simultaneous technique the rate of defibrillator damage appears to be exceedingly low. Further high-quality evidence is required to determine the impact of DSED on patient centered outcomes but the incidence of defibrillator damage should not appear to limit it use. The incidence of defibrillator damage should continue to be monitored in future trials and clinical practice.

Conflicts of Interest

Dr. Cheskes has received funding for educational seminars from Zoll Medical Corp. He has received research grant support from Zoll Medical Inc, Heart and Stroke Foundation of Canada and Cardiac Arrhythmia Network of Canada. He sits on the advisory board of Drone Delivery Canada. He is the PI of the ongoing Double Sequential External Defibrillation for Refractory Ventricular Fibrillation randomized controlled trial.

Dr. Drennan is the Vice-Chair of the ALS task force for the International Liaison Committee on Resuscitation (ILCOR) and member of the writing group for the 2020 AHA Guidelines for CPR and ECC.

Author Statement

All authors have met criteria for authorship and have made substantial contributions to the development of the project and final manuscript including conception and design of the study (IRD, SC, DS), acquisition of data (IRD, DS), analysis and interpretation of data (IRD, SC), drafting the article or revising it critically for important intellectual content (IRD, SC, DS) and final approval of the submitted version (IRD, SC, DS). All authors agree to be responsible for all aspects of submitted work.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2022.100287.

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