RESUSCITATION 201 (2024) 110286

Available online at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

The impact of time to defibrillation on return of spontaneous circulation in out-of-hospital cardiac arrest patients with recurrent shockable rhythms

Emad Awad[a,b,*], **Brent Klapthor**[a], **Michael H. Morgan**[a], **Scott T. Youngquist**[a,c]

Abstract

Objective: Optimal timing for subsequent defibrillation attempts for Out-of-hospital cardiac arrest (OHCA) patients with recurrent VF/pVT is uncertain. We investigated the relationship between VF/pVT duration and return of spontaneous circulation (ROSC) in OHCA patients with recurrent shockable rhythms.

Methods: We analyzed data from the Salt Lake City Fire Department (SLCFD) spanning from 2012 to 2023. The implementation of rhythm-filtering technology since 2011 enabled real-time rhythm interpretation during CPR, with local protocols allowing early defibrillation for recurrent/refractory VF/pVT cases. We included patients experiencing four or five episodes of VF and pVT rhythms and employed generalized estimating equation (GEE) regression analysis to examine the association between VF/pVT durations preceding recurrent defibrillation and return of spontaneous circulation (ROSC).

Results: Analysis of 622 appropriate shocks showed that patients achieving ROSC had significantly shorter median VF/pVT duration than those who did not achieve ROSC (0.83 minutes vs. 1.2 minutes, $p = 0.004$). Adjusted analysis of those with 4 VF/pVT episodes ($N = 142$) revealed that longer VF/pVT durations were associated with lower odds of achieving ROSC (odds ratio: 0.81, 95% CI: 0.72–0.93, $p = 0.005$). Every one-minute delay in intra-arrest defibrillation is predicted to decrease the likelihood of achieving ROSC by 19%.

Conclusion: Every one-minute increase in intra-arrest VF/pVT duration was associated with a statistically significant 19% decrease in the chance of achieving ROSC. This highlights the importance of reducing time to shock in managing recurrent VF/pVT. The findings suggest reevaluating the current recommendations of two minutes intervals for rhythm check and shock delivery.

Keywords: Cardiac arrest, Shockable rhythm, Defibrillation, Emergency medical services, Time to shock

Introduction

Rates of ventricular fibrillation (VF) and pulseless ventricular tachycardia (pVT) as the presenting rhythm in out-of-hospital cardiac arrest (OHCA) populations are highly variable and account for the initial rhythm in roughly 20 to 45% of OHCA cases.[1,2,3,4,5] The majority of OHCA patients who survive to hospital discharge present with VF.[2,6] Rates of survival after OHCA due to VF or pVT are believed to be primarily driven by time from arrest to initial defibrillation.[2,7,8] Animal models have illustrated that increased time in VF leads to increased myocardial ischemia and depletion of myocardial ATP stores.[9] Shorter duration of VF/ pVT and the amount of coronary arterial blood flow produced by CPR are thought to be the primary drivers of successful defibrillation.[2,7,10,11]

While time in VF/ pVT is detrimental to conversion to perfusing heart rhythms, animal research has also supported the belief that a short period of CPR prior to defibrillation may increase coronary blood flow and create an environment more conducive to return of spontaneous circulation (ROSC).[12–14] In 2005 the International Liaison Committee on Resuscitation (ILCOR) released guidelines with the major change of recommending a short period of effective CPR in unwitnessed OHCA due to VF prior to initial defibrillation.[15] Numerous studies, including three randomized controlled trials, have investigated the question of immediate defibrillation versus CPR preceding defibrillation in VF.[12,16–18] While a Cochrane review failed to

* Corresponding author at: Department of Emergency Medicine, 30 N Mario Capecchi Dr., HELIX 2 South, Salt Lake City, UT 84112, USA.
E-mail address: emad.awad@utah.edu (E. Awad).

https://doi.org/10.1016/j.resuscitation.2024.110286
Received 18 April 2024; Received in Revised form 26 May 2024; Accepted 13 June 2024

find evidence for superiority of either approach, ILCOR's most recent guidelines (2023) continue to recommend a brief period of CPR prior to defibrillation with a weak recommendation based on low-certainty evidence.[19,20]

While guidelines based largely on expert opinion generally recommend waiting for rhythm checks every two minutes before defibrillation, advancements in the use of adaptive filters for rhythm analysis allow for the possibility of identifying shockable rhythms while CPR is ongoing.[21] Prior work has established that the accuracy of paramedic rhythm interpretation using adaptive filtering is acceptable.[22] This raises the question of whether shockable rhythms should be defibrillated immediately upon recognition through adaptive filters or if compressions should continue with deferral of defibrillation until the next rhythm check. Eilevstjønn et al analyzed 1223 defibrillations across 221 unique VF arrest patients, finding that minimizing time to shock delivery improved outcomes, calling into question the current guideline recommendation of 2 min of uninterrupted CPR between defibrillation attempts when adaptive filters are available.[23] These findings have not been replicated. Moreover, relatively little research has been performed on time to subsequent defibrillation during CPR in recurrent VF/pVT. Studies that examine time to shock in patients who received four or five defibrillations for recurrent VF/pVT would account for more prolonged resuscitation efforts, indicative of severe cardiac events, and better capture the relationship between time to shock and the likelihood of achieving ROSC in recurrent VF/pVT.

Objective

The primary objective of this study was to investigate the relationship of intra-arrest VF/ pVT duration and ROSC in patients with OHCA presenting with recurrent/refractory VF or pVT requiring four or five shocks.

Methods

Study design and setting

We examined data from the Salt Lake City Fire Department (SLCFD) cardiac arrest registry collected between 2012 and 2023 for all OHCA patients in whom resuscitation was attempted. The registry contains administrative and clinical data on a range of variables, including patient demographics, prehospital resuscitation, VF/pVT duration ('time to shock'), and survival outcome. Defibrillator files are prospectively collected and analyzed as part of the quality assurance process for CPR quality and defibrillation accuracy. Cases are eligible for entry into the registry if the patient received a shock by a public access defibrillator or EMS performed CPR. The database excludes cases clearly caused by trauma, strangulation, or drowning, or cases in which family members represented that the patient had a healthcare directive prohibiting resuscitation.

EMS setting

SLCFD Emergency Medical Services (EMS) respond comprehensively to all arrest OHCA calls within a 111-square-mile area, managing approximately 128 OHCA emergency calls annually.[24] The department is comprised of approximately 340 Basic Life Support (BLS) and Advanced Life Support (ALS) providers, strategically stationed across 14 stations with 22 responding units. The local 911 dispatch center employs a tiered dispatch response matrix, guided by the Medical Priority Dispatch System protocols. In September 2011 the SLCFD adopted rhythm filtering technology in its defibrillator (Zoll R and later X Series, ZOLL Corp, Chelmsford, MA) and trained paramedics to interpret the rhythm during ongoing CPR. When a shockable rhythm is identified, paramedics are trained to pre-charge the defibrillator and countdown to shock delivery regardless of its occurrence during the traditional 2-minute rhythm analysis cycle.[25]

Study population

From the SLCFD Cardiac Arrest Registry, we created two analytic datasets. In the first one, we included all VF/pVT that received appropriate shocks along with their respective durations, and the response to each shock (i.e., whether ROSC was achieved or not). The second analytic dataset included adult patients who experienced OHCA with an initial presentation of VF or pVT who received four or five defibrillations for recurrent or persistent VF/pVT. Patients below 18 years of age, those with a non-shockable initial rhythm, those treated with a non-SLCFD defibrillator prior to EMS arrival, and patients receiving fewer than four defibrillations, or more than 5 defibrillators were excluded. The reason for excluding patients with more than five persistent VF/pVT was to mitigate confounding bias, as these patients may possess underlying characteristics (e.g., comorbidities, severity of cardiac condition, response to treatment) that influence both the number of shocks received and the likelihood of achieving ROSC. Failure to address these confounding factors could introduce bias into the estimated effect of time to shock on the odds of ROSC.

ECG analysis

As part of an in-depth quality assurance process, the medical director reviews each defibrillator file (ZOLL Code Review, Zoll Corp, Chelmsford, MA) and abstracts case events in long form in an excel spreadsheet and serves as the reference standard for rhythm interpretation. Events of interest include pauses and resumption of CPR > 10 s, shock delivery, and rhythm changes.[22]

Variables of interest and measurements

The independent variable was the VF/pVT duration. VF/pVT duration was defined as the time from the appearance of VF/pVT on the monitor until shock delivery, measured in minutes. Repeated episodes of VF/pVT were examined as repeated measures across five levels: VF/pVT durations 1, 2, 3, 4, and 5. The main outcome of interest was shock success, indicated by the presence of sustained or non-sustained ROSC within 20 second of shock delivery. ROSC was identified by evaluating the rhythm on the defibrillator screen and checking for a palpable pulse.

Data analysis

Shocked-based analysis

In this analysis, we recorded all VF/pVT cases that received appropriate shocks along with their respective durations, and recorded the response to each episode (i.e., whether ROSC was achieved or not). We then used the point biserial correlation to examine the bivariate association between VF/pVT duration and ROSC. Additionally, we conducted a Mann-Whitney U test to determine if there was a significant difference in VF/pVT duration between the group who achieved ROSC and those who did not. All analyses were performed using SPSS Version 29.

Patient-based analysis

In this analysis, we dealt with patients with VF/pVT as the units of study. We included all patients with initial VF/pVT who had four or five VF/pVT episodes during the resuscitation – including both recurrent VF/pVT (recurring after initial termination) and shock-resistant VF/pVT (failing to terminate).[26] We summarized the descriptive statistics of the characteristics of OHCA for the study group. To assess the impact of VF/pVT duration on the outcome, we employed Generalized Estimating Equations (GEE) logistic regression. This analytical method adjusts for the correlation among repeated measurements (VF/pVT durations) within the same subject, mitigating the risk of inflated Type 1 error rates (false positives). Specifically, we utilized the unstructured correlation structure in our GEE analysis to accommodate the varying correlation patterns between repeated measures of time to shock in OHCA patients. We used a theory-guided approach to select other covariates for our model. Variables that are clinically relevant and have known associations with the outcome were included. These analyses were conducted using R, version 4.3.1. This study received an ethical exemption from the University of Utah Research Ethics Board (IRB 00138043).

Results

Shock-based analysis

A total of 891 shocks were delivered. Among these, 243 were inappropriate shocks and excluded, and 26 cases/shocks were missing data on the corresponding VF/ pVT duration or ROSC, which were also excluded. The remaining 622 shocks were deemed appropriate and included in the analysis (Fig. 1). Among these, 204 shocks (32.8%) resulted in ROSC, while 418 shocks (67.2%) did not produce ROSC. The point-biserial correlation coefficient (r) was −0.3, indicating a negative correlation between VF/pVT duration and achieving ROSC. The Mann-Whitney *U* test revealed a significantly shorter VF/pVT duration in the group who achieved ROSC compared to the group that did not (median VF/pVT duration for ROSC group: 0.83 min, for No ROSC group: 1.28 min, p = 0.004) (Fig. 2).

Patient-based analysis

In this analysis, we dealt with individual patients as the unit of study. Initially, we identified 334 non-traumatic OHCA patients with recurrent VF/pVT. Of these, 15 were excluded due to missing data on key variables, 60 were excluded for having fewer than 4 episodes of VF/pVT, and 117 were excluded for having more than five episodes of VF/pVT. The remaining 142 cases met the inclusion criteria and were included in this analysis (Fig. 3). Of those, 104 had VF as the initial rhythm and 38 had pVT as the initial rhythm. Their cohort mean age was 59.5 ± 14.9 years. Among them, 105 (73.9%) were males, 63 (44.4%) experienced cardiac arrest in a public location, and 107 (75.4%) received bystander CPR. In terms of outcomes, 70 (49.3%) achieved ROSC, 56 (39.4%) survived hospital admission, 38 (26.8%) survived hospital discharge, and 32 (22.5%) survived with favorable neurological function at discharge. Table 1 provides a summary of descriptive statistics for the group baseline characteristics and crude survival rates.

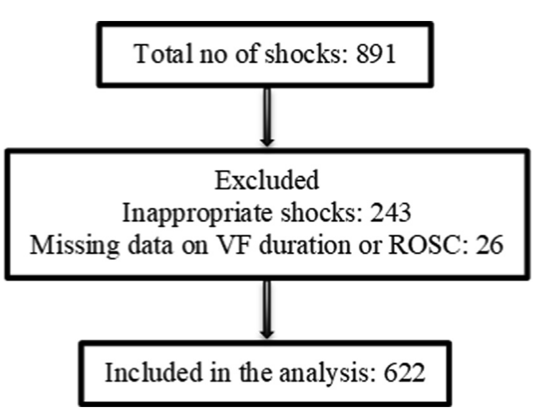

Fig. 1 – Shocks included in the analysis.

Results from GEE logistic regression analysis

The results from the GEE are presented in Table 2. For the ROSC outcome, the analysis revealed a VF/pVT duration beta coefficient of – 0.20, indicating a negative association between VF/pVT and log odds of achieving ROSC. The odds ratio (OR) was 0.81 (95% 0.72– 0.93, P = 0.005), indicating that, for each one-minute increase in VF/pVT duration, the odds of achieving ROSC decrease by about 19%, holding all other variables constant (Table 2).

Discussion

This study investigated the impact of initial and intra-arrest VF/pVT duration on achieving ROSC in patients experiencing OHCA with an initial shockable rhythm and four or five episodes of recurrent VF/pVT. The main finding from our unadjusted shock-based analysis revealed a statistically significant negative correlation between VF/ pVT duration and ROSC, with a shorter VF/pVT duration associated with a higher probability of achieving ROSC. This is consistent with existing literature that emphasizes the time-sensitivity of VF/pVT and the decreasing chances of successful defibrillation with prolonged VF/pVT duration.[27] It is worth noting that in the shock-based analysis, we found that 27.3% of the shocks were inappropriate. This could possibly be due to misinterpretation of the rhythms and interpreting artifacts as ventricular fibrillation (VF). Proper evaluation and management of cardiac rhythms during resuscitation are crucial to minimize these occurrences.

Furthermore, our multivariable patient-based analysis, utilizing GEE modeling, demonstrated that with each one-minute increase in VF/pVT duration, there was a statistically significant 19% decrease in the odds of achieving ROSC. This result highlights the importance of timely intervention during OHCA episodes characterized by recurrent VF/pVT. The findings suggest that prolonged VF/pVT duration impedes successful resuscitation efforts. Strategies for reducing time to shock in managing recurrent VF/pVT should be tested to enhance the likelihood of achieving ROSC.

Our results align with previous research, which consistently shows that a shorter time to defibrillation increases the likelihood of achieving ROSC. A study by Larsen et al. reported that for every minute of delay in CPR and defibrillation, the probability of ROSC decreases by 7–10%.[28] Similarly, research by Valenzuela et al. demonstrated that survival rates significantly improve when defibrillation occurs within the first few minutes of collapse.[29] Several other studies have found that a shorter duration of shockable rhythm is associated with a better chance of survival.[23] However, these previous studies focused on time to shock for initial rhythms only, while our study assesses time to shock for initial and subsequent VF/ pVT rhythms. Nevertheless, both our findings and previous studies highlight the importance of rapid response to OHCA and minimizing VF/pVT duration to enhance survival outcomes in VF-related OHCAs. Therefore, efforts to minimize the duration of VF/pVT through rapid response and high-quality resuscitation practices

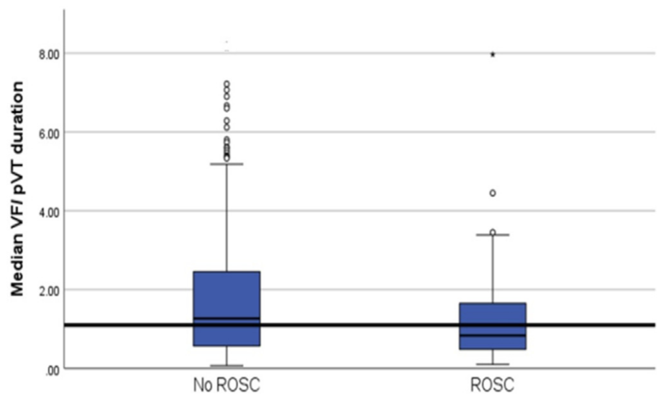

Fig. 2 – Difference in the median VF/pVT duration between ROSC and No ROSC group.

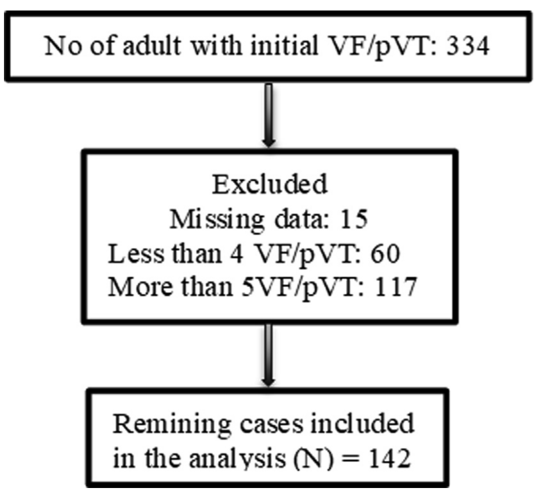

Fig. 3 – OHCA cases included in the analysis.

should remain a priority. While our study shows the prehospital use of adaptive filters on rhythm interpretation during cardiac arrest to be imperfect, with over one-third of shocks being delivered inappropriately, the benefit of more rapid time to shock may outweigh this finding.

The current guidelines by AHA, which recommend a two-minute interval for checking pulse and delivering shock, may require reevaluation, potentially through rigorous clinical trials. We believe our study can serve as a foundation for a clinical trial where the treatment group receives ongoing adaptive filter rhythm analysis with shocks given up to every minute while the control group receives standard treatment (rhythm check and shock every two minutes). This is particularly important given the complexity and variability present in OHCA events, where factors such as time to initial CPR, underlying comorbidities, and the administration of resuscitation medications may potentially confound the independent effect of the VF duration (timing of shocks) on patient outcomes. [6,30–32]

One strength of our study is the use of GEE analysis. GEE accounts for the correlation between repeated measures within subjects.[33] Additionally, GEE provides robust estimates of regression parameters even when the correlation structure is mis-specified or

Table 1 – Baseline characteristics and survival rates.

Variable	N = 142*
Age (years)	59.7 ± 14.9
911 to EMS arrival	
More than 7 min	79 (55.6%)
7 min or less	63 (44.4%)
Gender	
Male	105 (73.9%)
Female	37 (26.1%)
Arrest location	
Private	79 (55.6%)
Public	63 (44.4%)
Witness status	
Unwitnessed	41 (28.9%)
Witnessed	101 (71.1%)
Bystander CPR	
Not provided	35 (24.6%)
Bystander CPR	107 (75.4%)
Pause duration	
More than 15 sec	82 (57.7%)
15 sec or less	60 (42.3%)
Antiarrhythmic	
No	61 (43.0%)
Yes	81 (57.0%)
Epinephrine	
No	6 (4.2%)
Yes	136 (95.8%)
Ethnicity	
Non-White	51 (35.9%)
White	91 (64.1%)
ROSC	
Not achieved	72 (50.7%)
Achieved	70 (49.3%)
Hospital admission	
No	86 (60.6%)
Yes	56 (39.4%)
Hospital discharge	
Dead	104 (73.2%)
Alive	38 (26.8%)
Neuro outcome	
Unfavorable	110 (77.5%)
Favorable	32 (22.5%)

* N = 142 (104 had VF as the initial rhythm, and 38 had pVT).

Table 2 – Effect of VF/pVT duration on ROSC: GEE model.

Variable	Beta Coeff	OR	(95% CI)	*P* value
VF/ pVT duration	−0.20	0.81	0.72 – 0.93	<0.001
Age	−0.02	0.99	0.97 – 1.02	0.43
Male sex	−0.43	0.65	0.33 – 1.29	0.21
Response time > 7 min	−0.76	0.47	0.23 – 0.97	0.04
Location	0.68	1.98	1.08 – 3.62	0.03
Witness status	0.62	1.86	0.85 – 4.08	0.12
Bystander CPR	1.03	2.81	1.24 – 6.36	0.01
Anti-Arrhythmic	−0.28	0.76	0.40 – 1.41	0.38
Epinephrine	−0.24	0.79	0.59 – 1.05	0.10
Pause duration > 15 sec	−0.28	0.75	0.34 – 1.66	0.43

*N = 142 (104 had VF as the initial rhythm, and 38 had pVT).

unknown. This is particularly valuable in real-world data analysis like OHCA data where the underlying correlation structure may be complex.

Limitations

We utilized data from a local Utstein-style OHCA registry. The results may not be generalizable to other regions with different resuscitation protocols. Additionally, the short time to defibrillation in our cohort reduced variability in the upper limits of time to defibrillation. Furthermore, it's important to acknowledge that our analysis may not have accounted for all influential factors, such as chest compression rate, preceding rhythms before the recurrence of VF/pVT, comorbidities, medications, and hormonal influences. Including these variables could either weaken or strengthen the observed odds of survival. Including these variables could either attenuate or strengthen the observed odds of survival. Another limitation of our study is the occurrence of inappropriate shocks during resuscitation efforts. These shocks may have led to interruptions in CPR, potentially affecting the quality of chest compressions and overall patient outcome. Given the significance of our findings, we strongly recommend conducting a systematic review or a clinical trial to validate our conclusion regarding the correlation between shorter VF/pVT duration and increased chance of survival.

Conclusion

This study found that a longer VF/pVT duration is significantly associated with a lower chance of achieving ROSC. More specifically, for each one-minute increase in VF/pVT duration, the odds of achieving ROSC decrease by 19%. These results emphasize the necessity of reducing time to shock in managing recurrent VF/pVT. We propose the reevaluation of current OHCA resuscitation guidelines recommending a two-minute interval for rhythm checks and shock delivery, potentially through clinical trials or systematic review.

CRediT authorship contribution statement

Emad Awad: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Brent Klapthor:** Writing – review & editing, Validation, Methodology, Conceptualization. **Michael H. Morgan:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Scott T. Youngquist:** Writing – review & editing, Supervision, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author details

[a]Department of Emergency Medicine, Faculty of Medicine, University of Utah, Salt Lake City, UT, USA [b]BC RESURECT: Department of Emergency Medicine, University of British Columbia, Vancouver, BC, Canada [c]Salt Lake City Fire Department (SLCFD), Salt Lake City, UT, USA

REFERENCES

1 Ko BS, Kim YJ, Han KS, et al. Association between the number of prehospital defibrillation attempts and a sustained return of spontaneous circulation: a retrospective, multicentre, registry-based study. Emerg Med J 2023;40(6):424–30. https://doi.org/10.1136/emermed-2021-212091.

2 Valenzuela TD, Roe DJ, Cretin S, Spaite DW, Larsen MP. Estimating Effectiveness of Cardiac Arrest Interventions. Circulation 1997;96:3308–13. https://doi.org/10.1161/01.CIR.96.10.3308.

3 Nichol G, Sayre MR, Guerra F, Poole J. Defibrillation for Ventricular Fibrillation. J Am Coll Cardiol 2017;70:1496–509. https://doi.org/10.1016/j.jacc.2017.07.778.

4 Rea T, Kudenchuk PJ, Sayre MR, Doll A, Eisenberg M. Out of hospital cardiac arrest: Past, present, and future. Resuscitation 2021;165:101–9. https://doi.org/10.1016/j.resuscitation.2021.06.010.

5 Rea TD, Eisenberg MS, Sinibaldi G, White RD. Incidence of EMS-treated out-of-hospital cardiac arrest in the United States. Resuscitation 2004;63:17–24. https://doi.org/10.1016/j.resuscitation.2004.03.025.

6 Awad EM, Humphries KH, Grunau BE, Norris CM, Christenson JM. Predictors of neurological outcome after out-of-hospital cardiac arrest: sex-based analysis: do males derive greater benefit from hypothermia management than females? Int J Emerg Med 2022;15:43. https://doi.org/10.1186/s12245-022-00447-z.

7 Soar J, Böttiger BW, Carli P, et al. European Resuscitation Council Guidelines 2021: Adult advanced life support. Resuscitation 2021;161:115–51. https://doi.org/10.1016/j.resuscitation.2021.02.010.
8 Panchal AR, Bartos JA, Cabañas JG, et al. Part 3: Adult basic and advanced life support: 2020 American heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2020;142:S366–468. https://doi.org/10.1161/CIR.0000000000000916.
9 Kern KB, Garewal HS, Sanders AB, et al. Depletion of myocardial adenosine triphosphate during prolonged untreated ventricular fibrillation: effect on defibrillation success. Resuscitation 1990;20:221–9. https://doi.org/10.1016/0300-9572(90)90005-Y.
10 Menegazzi JJ, Wang HE, Lightfoot CB, et al. Immediate defibrillation versus interventions first in a swine model of prolonged ventricular fibrillation. Resuscitation 2003;59:261–70. https://doi.org/10.1016/S0300-9572(03)00212-0.
11 Eftestøl T, Wik L, Sunde K, Steen PA. Effects of cardiopulmonary resuscitation on predictors of ventricular fibrillation defibrillation success during out-of-hospital cardiac arrest. Circulation 2004;110:10–5. https://doi.org/10.1161/01.CIR.0000133323.15565.75.
12 Simpson PM, Goodger MS, Bendall JC. Delayed versus immediate defibrillation for out-of-hospital cardiac arrest due to ventricular fibrillation: A systematic review and meta-analysis of randomised controlled trials. Resuscitation 2010;81:925–31. https://doi.org/10.1016/j.resuscitation.2010.04.016.
13 Kolarova J, Ayoub IM, Yi Z, Gazmuri RJ. Optimal timing for electrical defibrillation after prolonged untreated ventricular fibrillation. Crit Care Med 2003;31:2022–8. https://doi.org/10.1097/01.CCM.0000070446.84095.F4.
14 Berg RA, Hilwig RW, Kern KB, Ewy GA. Precountershock cardiopulmonary resuscitation improves ventricular fibrillation median frequency and myocardial readiness for successful defibrillation from prolonged ventricular fibrillation: A randomized, controlled swine study. Ann Emerg Med 2002;40:563–71. https://doi.org/10.1067/mem.2002.129866.
15 Hazinski MF, Nadkarni VM, Hickey RW, O'Connor R, Becker LB, Zaritsky A. Major Changes in the 2005 AHA Guidelines for CPR and ECC. Circulation 2005;112. https://doi.org/10.1161/CIRCULATIONAHA.105.170809.
16 Wik L, Hansen TB, Fylling F, et al. Delaying defibrillation to give basic cardiopulmonary resuscitation to patients with out-of-hospital ventricular fibrillation. JAMA 2003;289:1389. https://doi.org/10.1001/jama.289.11.1389.
17 Baker PW, Conway J, Cotton C, et al. Defibrillation or cardiopulmonary resuscitation first for patients with out-of-hospital cardiac arrests found by paramedics to be in ventricular fibrillation? A Randomised Control Trial. Resuscitation 2008;79:424–31. https://doi.org/10.1016/j.resuscitation.2008.07.017.
18 Jacobs IG, Finn JC, Oxer HF, Jelinek GA. CPR before defibrillation in out-of-hospital cardiac arrest: A randomized trial. Emerg Med Australas 2005;17:39–45. https://doi.org/10.1111/j.1742-6723.2005.00694.x.
19 Huang Y, He Q, Yang LJ, Liu GJ, Jones A. Cardiopulmonary resuscitation (CPR) plus delayed defibrillation versus immediate defibrillation for out-of-hospital cardiac arrest. Cochrane Database Syst Rev 2014;2018. https://doi.org/10.1002/14651858.CD009803.pub2.
20 Berg KM, Bray JE, Ng KC, et al. 2023 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations: summary from the basic life support; advanced life support; pediatric life support; neonatal life support; Education I.. Circulation 2023;Epub ahead:1–94. https://doi.org/10.1161/CIR.0000000000001179.
21 Ruiz de Gauna S, Irusta U, Ruiz J, Ayala U, Aramendi E, Eftestøl T. Rhythm analysis during cardiopulmonary resuscitation: past, present, and future. Biomed Res Int 2014;2014:1–13. https://doi.org/10.1155/2014/386010.
22 Stoecklein HH, Pugh A, Johnson MA, et al. Paramedic rhythm interpretation misclassification is associated with poor survival from out-of-hospital cardiac arrest. Resuscitation 2022;171:33–40. https://doi.org/10.1016/j.resuscitation.2021.12.016.
23 Eilevstjønn J, Kramer-Johansen J, Sunde K. Shock outcome is related to prior rhythm and duration of ventricular fibrillation. Resuscitation 2007;75:60–7. https://doi.org/10.1016/j.resuscitation.2007.02.014.
24 Awad E, Hopkins C, Palatinus H, Hunt-Smith TT, Ryba C, Youngquist S. Epidemiology and outcome of out-of-hospital cardiac arrest in Salt Lake City: Sex-based investigations. J Am Coll Emerg Physicians Open. 2024 May 21;5(3):e13189. https://doi.org/10.1002/emp2.13189. PMID: 38774259; PMCID: PMC11107878.
25 Hopkins CL, Burk C, Moser S, Meersman J, Baldwin C, Youngquist ST. Implementation of pit crew approach and cardiopulmonary resuscitation metrics for out-of-hospital cardiac arrest improves patient survival and neurological outcome. J Am Heart Assoc 2016;5. https://doi.org/10.1161/JAHA.115.002892.
26 Nas J, Thannhauser J, Bonnes JL, Brouwer MA. Importance of the distinction between recurrent and shock-resistant ventricular fibrillation: Call for a uniform definition of refractory VF. Resuscitation 2019;138:312–3. https://doi.org/10.1016/j.resuscitation.2019.01.042.
27 Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: A graphic model. Ann Emerg Med 1993;22:1652–8. https://doi.org/10.1016/S0196-0644(05)81302-2.
28 Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. N Engl J Med 2000;343:1206–9. https://doi.org/10.1056/NEJM200010263431701.
29 Agarwal DA, Hess EP, Atkinson EJ, White RD. Ventricular fibrillation in Rochester, Minnesota: experience over 18 years. Resuscitation 2009;80:1253–8. https://doi.org/10.1016/j.resuscitation.2009.07.019.
30 Chan PS. Hospital variation in time to defibrillation after In-hospital cardiac arrest. Arch Intern Med 2009;169:1265. https://doi.org/10.1001/archinternmed.2009.196.
31 Martinell L, Nielsen N, Herlitz J, et al. Early predictors of poor outcome after out-of-hospital cardiac arrest. Crit Care 2017;21. https://doi.org/10.1186/s13054-017-1677-2.
32 Nichol G, Thomas E, Callaway CW, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. JAMA 2008;300:1423–31. https://doi.org/10.1001/jama.300.12.1423.
33 Horton NJ, Lipsitz SR. Review of software to fit generalized estimating equation regression models. Am Stat 1999;53:160. https://doi.org/10.2307/2685737.