

Clinical paper

The need to resume chest compressions immediately after defibrillation attempts: An analysis of post-shock rhythms and duration of pulselessness following out-of-hospital cardiac arrest[☆]



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ARTICLE INFO

Article history:

Received 29 August 2014

Received in revised form

10 December 2014

Accepted 15 December 2014

Keywords:

Cardiopulmonary arrest

Cardiopulmonary resuscitation

Asystole

Ventricular fibrillation

Defibrillation

Return of spontaneous circulation

ABSTRACT

Aim: Current consensus guidelines for cardiopulmonary resuscitation (CPR) recommend that chest compressions resume immediately after defibrillation attempts and that rhythm and pulse checks be deferred until completion of 5 compression:ventilation cycles or minimally for 2 min. However, data specifically confirming the post-shock duration of asystole or pulseless electrical activity before return of spontaneous circulation (ROSC) are lacking. Our aim was to describe the frequency of the various post-shock cardiac rhythms and the duration of post-shock pulselessness in out-of-hospital non-traumatic cardiac arrest.

Method: Using prospectively-collected data from the Resuscitation Outcomes Consortium (ROC) Epistry database, the investigators reviewed monitor-defibrillator recordings of 176 patients who received defibrillation attempts in the out-of-hospital setting for ventricular fibrillation (VF) or ventricular tachycardia (VT) with absent pulses.

Results: Among 376 different defibrillation attempts delivered in the 176 patients, there were 182 resulting episodes of post-shock asystole. The mean interval of asystole after defibrillation was 69 ± 136 s (median 20 s; IQR 36) and the mean interval for return of an organized rhythm was 64 ± 157 s (median 7 s; IQR 26). The mean time to ROSC was 280 ± 320 s (median 136 s; IQR 445).

Conclusion: After defibrillation attempts, the majority of patients remain pulseless for over 2 min and the duration of asystole before return of pulses is longer than 120 s beyond the shock gap in as many as 25%. These data support the recommendation to immediately resume chest compressions for 2 min following attempted defibrillation.

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1. Introduction

For the past decade, international guidelines for basic cardiopulmonary resuscitation (CPR) have emphasized a renewed focus on the quality of chest compressions including rate, depth, recoil and minimal interruptions in those compressions.¹ Recent advanced cardiac life support (ACLS) protocols also have stressed minimal interruptions in chest compressions, even delaying intubation attempts as a strategy to optimize both cardiac and cerebral perfusion in the early phases of resuscitative efforts.² Several studies

now indicate improvements in survival using such strategies.^{2–5} Subsequently, the 2010 American Heart Association (AHA) guidelines placed even greater emphasis on minimizing any delays in initiating chest compressions and limiting any “hands-off” intervals during all phases of resuscitation.⁶ Lay rescuers were no longer advised to check for pulses and to only assess for unresponsiveness and abnormal breathing while lone rescuers, for the first time, were instructed to begin chest compressions before the first assisted ventilation.⁶ If defibrillation was required, chest compressions were to be initiated and continued until a defibrillator was available and ready to deliver a defibrillatory shock.⁶ Also, guidelines recommended that chest compressions should be resumed immediately after a defibrillation attempt and continued for 5 compression:ventilation cycles (e.g., 30:2) or approximately 2 min (120 s) before reassessing for return of spontaneous circulation (ROSC) or the need for re-attempted defibrillation.⁶

[☆] A Spanish translated version of the summary of this article appears as Appendix in the final online version at <http://dx.doi.org/10.1016/j.resuscitation.2014.12.023>.

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Although immediate post-shock chest compressions have been associated with improved outcomes, data specifically confirming the post-shock duration of asystole or pulseless electrical activity (PEA) before return of spontaneous circulation (ROSC) are still lacking.^{7–10} In essence, the rationale for immediate resumption of chest compressions for as long as 5 compression:ventilation cycles (or 2 min) has not yet been analyzed explicitly.

Therefore, the specific aim of the current investigation was to catalog the frequency and distribution of the post-shock cardiac rhythms observed immediately after attempted defibrillation in patients with out-of-hospital cardiac arrest as well as the duration of pulselessness in these patients before they achieve any ROSC.

2. Method

2.1. Study design, setting and subject protection

The Resuscitation Outcomes Consortium (ROC) is a clinical trial network focusing on research and clinical trials in the arenas of out-of-hospital cardiopulmonary arrest and severe traumatic injury (<https://roc.uwctc.org/tiki/tiki-index.php?page=roc-public-home>). The ROC includes regional research centers throughout the United States (U.S.) and Canada and a U.S.-based data-coordinating center. The ROC established an epidemiologic registry (Epistry) for out-of-hospital cardiac arrest in December 2005. The Epistry collates high-quality, comprehensive, prospectively-collected, population-based, emergency medical services (EMS) system data. The datasets use uniform definitions and standardized criteria for reporting those data and include all consecutive cases of out-of-hospital cardiac arrest occurring in the study jurisdictions.

The current study utilized the regional center Epistry data collected at the Dallas–Fort Worth (DFW) ROC site during the 18 months between November 2009 and April 2011. Approval for the DFW participation in the Epistry database was obtained from the institutional review board of the University of Texas Southwestern Medical Center. The board waived the requirement for informed consent because this study was considered to meet criteria for minimal risk and utilized de-identified protected personal information for the participants.

In terms of funding sources, the Epistry is sponsored by the U.S. National Heart Lung and Blood Institute (NHLBI) and the AHA.

2.2. Study subjects

For this study, the investigators included out-of-hospital cardiac arrest patients ≥ 18 years of age who received defibrillation attempts by the EMS providers in the DFW ROC site for a electrocardiographic (ECG) rhythm of ventricular fibrillation (VF) or ventricular tachycardia (VT) with absent pulses at any time during the resuscitation. Recognizing that the same patient could receive numerous attempts, multiple defibrillation attempts, even in the same patient were analyzed. Patients with post-traumatic cardiac arrest or other non-cardiac causes of arrest were excluded.

2.3. Data collection

For the Epistry database, data were collected using standardized data element forms and uniform definitions developed by ROC investigators. Research personnel followed standardized procedures for data collection to ensure the validity and reproducibility of the data. Trained research personnel identified and collected the electronic patient care record (EPCR) of patients with out-of-hospital cardiac arrest within 24 h of the cardiac arrest event. ECG tracings were automatically recorded by monitor-defibrillator units or automated external defibrillators (AEDs) carried by paramedics and firefighters (Physio-Control LIFEPAK®

500 AED, LIFEPAK® 12, and LIFEPAK® 15, Redmond, WA). Also, investigators in the current study manually reviewed the data for each case entered into the Epistry database for subjects meeting inclusion criteria. The information extracted from the database was originally entered as follows: (1) abstracted EMS incident reports for prehospital time intervals, the prehospital CPR process, and the ECG to be uploaded; (2) recorded time intervals documented from the dispatch report, the EPCR, and additional information taken directly from the EMS personnel's 9-1-1 incident reports; (3) downloads for each ECG that were analyzed by research personnel and then entered into the ROC Epistry database; (4) time elapsed until ROSC abstracted from time intervals documented on the EMS personnel's EPCR which included rhythm analysis and increases in end-tidal carbon dioxide (EtCO₂). The defibrillator data were transferred from the defibrillators into the CODE-Stat Suite Data Management System (Version 9.0, Medtronic Physio-Control). Intervals were calculated by reviewing ECG tracings using CODE-stat software.

2.4. Outcome measures

For the purposes of this study, an organized rhythm was defined as multiple similar ventricular (QRS) complexes that produced a consistent rhythm. The primary outcomes examined were the frequency and duration of asystole as well as the duration of pulselessness following a defibrillatory shock among those achieving ROSC. ROSC was defined as the time when a spontaneous palpable pulse was first detected in any vessel.

2.5. Data analysis

Each case was reviewed independently by two of the authors of this investigation, who reviewed each record separately, and then jointly, to ensure consistency and that the information extracted from each record was correct.

The following data were abstracted from the database: (1) demographic information including age, sex, race; date of defibrillation; (2) public or non-public location of arrest; (3) witnessed or unwitnessed arrest; (4) bystander CPR performed; bystander AED use; (5) airway device used including bag-valve mask, supraglottic airway or endotracheal tube; (6) medications given including adrenaline (epinephrine), atropine, amiodarone, lidocaine or sodium bicarbonate; (7) time of first chest compressions documented by EMS; (8) time of first ROSC documented by EMS; (9) time of first EMS cardiac arrest rhythm and rhythm interpretation by EMS; (10) total number of defibrillations received by each patient; (11) rhythm strip recordings of defibrillations; and (12) patient outcome including survival to hospital discharge, death in hospital as an inpatient or in the emergency department (ED), or field termination of resuscitation efforts.

Monitor-defibrillators recorded cardiac rhythms, defibrillation attempts and chest compressions. The investigators reviewed the electronic recordings for the first three episodes of attempted defibrillation for each patient. If there were more than three episodes of attempted defibrillation, they reviewed the first three episodes of attempted defibrillation and any subsequent episode that resulted in return of an organized rhythm or ROSC. For each episode of attempted defibrillation (shock), the following information was recorded by the investigators: (1) time of the shock; (2) the amount of energy used in Joules for each shock; (3) the hands-off interval for CPR before and after each shock; (4) the "shock gap" (defined as the interval after the shock in which no rhythm could be identified on the rhythm tracing when the defibrillator transiently shuts off monitoring functions during delivery of the shock, typically lasting 2 to 5 s); (5) time interval from the shock to first identifiable

Table 1
Study population demographic and clinical data.

Parameter	Number
Total patients	176
Age in years, (mean $\pm$ SD)	61 $\pm$ 17
Male gender	118
Female gender	57
Gender not documented	1
Bystander witnessed	74
Bystander CPR	51
Public location	46
Return of spontaneous circulation (%)	51 (29%)
Survival to discharge (%)	18 (10%)
Presenting rhythm	
VF/VT	111
PEA	21
Asystole	41
AED—no shock	3

rhythm; (6) time interval of asystole, which was defined as the time when asystole could first be identified after the shock gap until a non-asystolic (VF/VT/organized) rhythm was first observed; (7) time interval from the shock to the appearance of two consecutive, similar QRS complexes (organized rhythm); and (8) time interval from defibrillation to ROSC, including the rhythm noted at the time of ROSC.

The data were analyzed with StatView 4.5 software (Abacus Concepts, Berkeley, CA). The time interval data were reported as mean $\pm$ SD as well as the median with interquartile range (IQR).

3. Results

During the 18 months of study, 176 patients received one or more attempts at defibrillation for VF or VT with absence of pulses (Figs. 1 and 2). Demographic characteristics of the study population are displayed in Table 1. Among the 176 patients, 376 different episodes of attempted defibrillation were reviewed. The distribution of post-shock rhythms after each defibrillation attempt are shown in Table 2. Asystole was identified as the initial post-shock gap rhythm in 206 (55%) of the 376 episodes of attempted defibrillation. Among those episodes, 157 (76%) lasted from 1 to 119 s, 25 (12%) lasted 120 to 1098 s, and 24 (12%) episodes of attempted defibrillation resulted in sustained asystole (Fig. 3). The subsequent rhythms that occurred after any interval of asystole included: 186 (49%) episodes of pulseless electrical activity (PEA); 153 (41%) episodes of VF; 25 (7%) episodes of persistent asystole; 7 (2%) episodes of VT; 3 (1%) episodes of sinus rhythm; 1 (<1%) episode of a junctional rhythm; and 1 (<1%) rhythm that was not documented. The mean interval of asystole after defibrillation was 69 $\pm$ 136 s (range 0 to 1098 s), median 20 s and IQR 36 s. The mean time to return of an organized rhythm after defibrillation was 64 $\pm$ 157 s, median 7 s and IQR 26 s. The mean time to ROSC after defibrillation was 280 $\pm$ 320 s, median 136 s and IQR 445 (Table 3).

There were 217 episodes of defibrillation that eventually resulted in the return of an organized rhythm. Return of an organized rhythm occurred after the first defibrillation in 112 episodes, 51 episodes after the second defibrillation, 38 episodes after the

third defibrillation, and 16 episodes occurred with the fourth or subsequent defibrillation attempt.

ROSC occurred in 51 (29%) of the 176 patients and 18 patients (10%) survived to hospital discharge. The defibrillation energies that immediately preceded a ROSC event were as follows: 200 J for 29 patients, 300 J for eight, 360 J for nine and 70 J in one case. Four were shocked in the ED where details of the defibrillation were not obtained. Among those regaining pulses, the mean interval of asystole before ROSC was 77 $\pm$ 142 s (2–605 s), median 20 s (IQR 59 s). Of those who had ROSC, only 45% (23/51) achieved ROSC after the first shock, 22% (11/51) after the second shock, 15.6% (8/51) after the third shock, 15.6% (8/51) after the fourth shock. The first rhythm after the shock that resulted in ROSC was PEA for 82.4% of subjects (42/51), sinus rhythm in 6% (3/51), VT in 4% (2/51), and a junctional rhythm in one patient.

Forty-one episodes of attempted defibrillation were reviewed for the 18 patients who survived to hospital discharge with 11 (27%) episodes of post-shock asystole noted. The mean interval of asystole in the survivors was 42 $\pm$ 69 s (median 13 s, IQR 33, range 3–245 s). Four of the eighteen survivors had at least one period of post-shock asystole before achieving ROSC following that shock. After the defibrillation that resulted in ROSC, the mean time to ROSC was 93 $\pm$ 124 s (range 3–413 s) for the surviving patients. The mean number of defibrillation attempts in patients that eventually achieve ROSC was 2.6 (median 2). Two-thirds of the survivors (12/18) had a bystander witnessed arrest and half (9/18) received CPR by bystanders.

4. Discussion

With the evolving evidence that minimally-interrupted CPR was critical to resuscitation, the 2010 AHA consensus guidelines for resuscitation efforts strongly recommended immediate resumption of chest compressions after each defibrillation attempt emphasizing that chest compressions should not be interrupted and that they not be delayed for rhythm analysis or pulse check immediately after the shock.^{6,11} The current investigation confirmed the continued absence of pulses for at least 2 min in the majority of post-shock events and that as many as 25% even remained in asystole for over 120 s beyond the shock gap. In turn, the recommendation that chest compressions should resume immediately after defibrillation without pausing to check the rhythm or pulses has clear validity.

According to numerous reports, interruptions in chest compressions are common and have been associated with a decreased probability of converting VF to another rhythm.¹² These interruptions in chest compressions can also reduce the likelihood of ROSC and thus, patient survival.^{7,9,12–17} Two previous case series found that a palpable pulse was rarely present immediately after defibrillation, providing additional supporting evidence that chest compressions should be resumed immediately after delivery of the shock.^{18,19} In the current study, not only was there an absence of pulses immediately after the shock, but the return of an organized rhythm took 1 min on average. Furthermore, the mean time interval from a defibrillation attempt to ROSC was at least three times longer.

Table 2
Electrocardiographic rhythms after defibrillation attempts and any interval of asystole.

	Ventricular fibrillation (N)	Ventricular tachycardia (N)	Pulseless electrical activity (N)	Asystole (N)	Sinus rhythm, junctional rhythm (N)
First shock	59	4	96	17	0
Second shock	45	2	46	4	2
Third shock	29	0	31	3	1
Fourth shock	20	1	13	1	2

1. V. Fib 2. Shock 3. Shock Gap 4. Interval of Asystole 5. Compressions (green)



6. Organized Rhythm

Fig. 1. A monitor-defibrillator electrocardiographic (ECG) record from a representative patient. The ECG record from the monitor showing initial ventricular fibrillation,¹ then defibrillation/shock² with the energy delivered in Joules, followed by a shock gap³ (interval after defibrillation in which no rhythm could be identified on the rhythm strip), followed by the interval of asystole⁴ (the time after the shock gap where asystole could be identified until a non-asystolic rhythm was observed). Chest compressions⁵ are resumed, followed by slow intrinsic organized QRS complexes/organized rhythm during chest compressions. The organized rhythm⁶ increases in rate and can be seen during CPR and when CPR is stopped.

Table 3

Interval times after defibrillation interval times following 376 episodes of attempted defibrillation in 176 patients with ventricular fibrillation or pulseless ventricular tachycardia.

Interval	Mean times	Median (IQR)
Interval of asystole (s) (N=176)	69 ± 136	20 (36)
Time to return of an organized rhythm (s) (N=104)	64 ± 157	7 (26)
Time to return of spontaneous circulation (s) (N=22)	280 ± 320	136 (445)

With the expanded use of ultrasound in the ED, cardiac activity has been visualized on ultrasound before palpable pulses are detected. However, cardiac contractile activity, and thus, cardiac output, may still be insufficient to provide adequate perfusion to vital organs. Also, high quality chest compressions may augment any spontaneous perfusion provided by a newly resuscitated heart. This notion has been supported by the findings of other investigations. In one study of 35 patients with 96 defibrillation attempts, there was a 10-fold increase in ROSC when the post-shock interval from the time of defibrillation to the initiation of chest compressions was less than 6 s.⁸ Other studies have also indicated improvements in survival with post-shock-to-compression intervals of less than 10 s.^{9,19}

A defibrillation attempt is not without complications. It may not be successful in many cases and it can induce arrhythmias or result in myocardial stunning. However, those are all acceptable risks because defibrillation is the most definitive therapy for patients presenting with cardiac arrest due to VF or VT.²⁰ Despite risks such as rib fractures, life-threatening complications from performing chest compressions are rare.²¹ One study did suggest that chest compressions could cause the recurrence of VF after the first successful conversion in patients with out-of-hospital cardiac arrest.²² However, the results of this current study indicate that with the high frequency of persistent pulselessness, immediately resuming chest compressions is certainly indicated and that circumstance outweighs other putative risks for the majority of patients.

Among those regaining pulses, the majority did not achieve ROSC within 2 min and it took as long as 10 min after the first shock in some cases. Therefore, the question that remains is whether or not the period of chest compressions following defibrillation should

be extended beyond 2 min. Despite the findings of this study, what is still not established is the optimum duration of uninterrupted chest compressions following defibrillation attempts.

One could also argue that extending the period of time for chest compressions beyond 2 min after defibrillation could also result in a clinically significant delay for a repeated attempt at defibrillation.²³ Although newer technology has been developed that could filter out CPR motion artifact and better enable rhythm assessment during chest compressions, rhythm analysis is still not sufficiently accurate while chest compressions are being performed and it could be argued that additional perfusion benefits may be obtained from a finite period of post-shock chest compressions.²⁴ Thus, the current guidelines of performing 2 min of chest compressions immediately following each defibrillation attempt followed by reassessment of the patient is probably a reasonable balance of risk versus benefit in the resuscitation of victims of sudden cardiac arrest.

1.V. Fib



2, QRS complexes

Fig. 2. A monitor-defibrillator electrocardiographic (ECG) record from a representative patient. The ECG record from the monitor showing initial ventricular fibrillation,¹ then defibrillation/shock with the energy delivered in Joules, followed by a shock gap (interval after defibrillation in which no rhythm could be identified on the rhythm strip), followed by the interval of asystole (the time after the shock gap where asystole could be identified until a non-asystolic rhythm was observed). Slow intrinsic organized QRS complexes appear² appears and then the organized rhythm increases in rate.

1. V. Fib

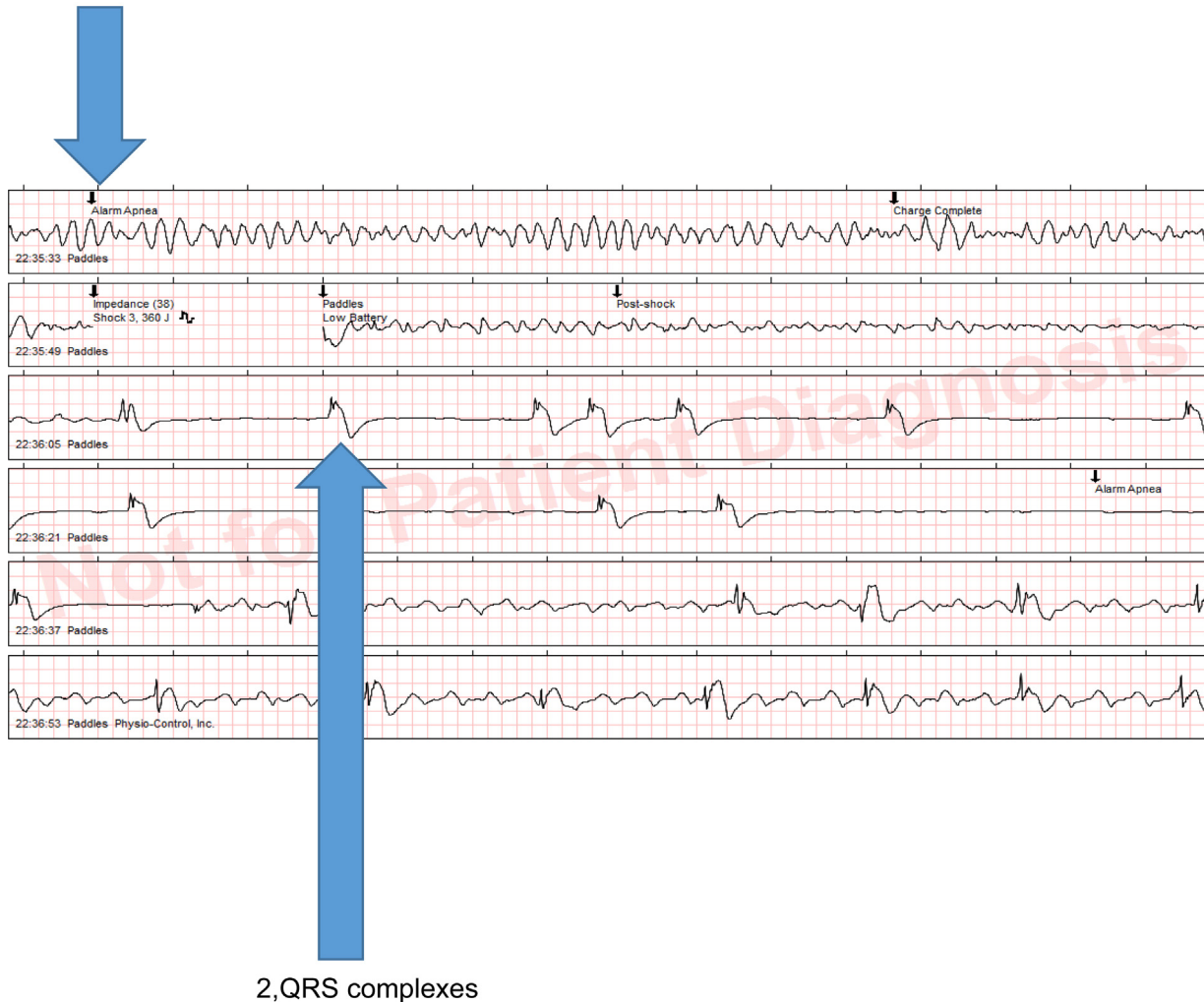


Fig. 2. (Continued)

Whatever the optimal approach may be, the findings in this study clearly indicate that, for the clear majority of patients, chest compressions should indeed be immediately resumed after a shock is delivered.

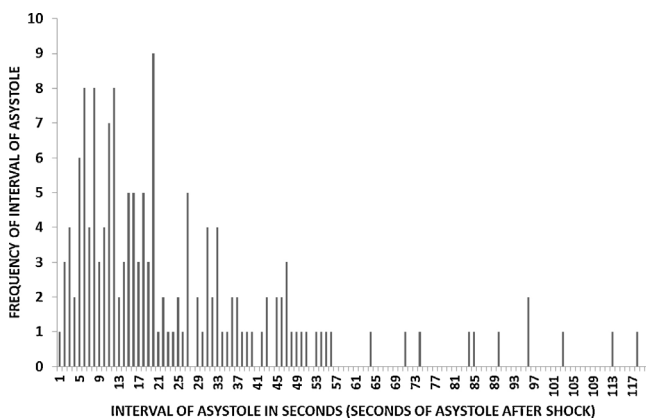


Fig. 3. Seconds of asystole (defined in the study as the interval of asystole) after 157 episodes of attempted defibrillation with the frequency that each interval of asystole occurred in this study. Twenty-five episodes of defibrillation had intervals of asystole between 128 and 1098 s (not depicted on the chart).

5. Limitations

While this study was a post hoc analysis, the data were collected prospectively in all consecutive cases occurring in the local population with standardized definitions, data collection methodologies and reporting for participation in the Epistry database. In turn, this methodology minimizes the typical concerns for post hoc analysis.

All agencies that participate in the ROC Epistry use monitor-defibrillators capable of recording electronic files of cardiac rhythms, defibrillations, and chest compressions. Communities that use devices that cannot record electronic files could possibly have different results, perhaps related to differences in socioeconomic status and lack of monitoring for quality of CPR. While the investigators in this study only reviewed cases from the DFW ROC site, the communities involved had significant diversity in terms of such demographics and it could be argued that lack of quality monitoring would only amplify findings of post-shock asystole and pulselessness. Nevertheless, it would still be recommended that a larger, multi-centered study would be useful to confirm the findings in DFW.

One other potential limitation in methodology was that we reviewed only the first three defibrillation attempts and the subsequent episode of defibrillation that resulted in return of an organized rhythm or ROSC. Several patients had more than four

episodes of defibrillation, which possibly could be an effect-modifying variable, but given the nature of prolonged resuscitation efforts, it is likely not enough of a modifier to alter the basic finding that most patients remain pulseless as long as 2 min post-shock.

6. Conclusion

The majority of patients remain pulseless for more than 2 min following a defibrillation attempt. Moreover, the post-shock duration of asystole before return of spontaneous circulation (ROSC) is longer than 120 s in as many as 25% of patients and the interval of asystole in the patients who survive to hospital discharge can be as long as 35 s. In summary, the findings of this comprehensive study support the recommendation to immediately resume chest compressions following attempted defibrillation and to continue CPR for two more minutes before assessing for spontaneous pulses or the cardiac rhythm.

Sources of funding

This study was supported by cooperative agreements to The University of Texas Southwestern Medical Center (HL077887), one of the regional clinical centers in the ROC, from the National Heart, Lung and Blood Institute in partnership with the American Heart Association.

Disclosures

Dr. A.H. Idris and P.C. Owens have received grant funding from the ROC, NHLBI, and the American Heart Association. Dr. A.H. Idris serves as an unpaid consultant for Philips Medical Systems. Dr. Idris is a volunteer for the American Heart Association National Emergency Cardiovascular Care Committee.

Acknowledgments

The investigators express their deepest appreciation for the unwavering dedication of the EMS personnel participating in the Dallas-Forth Worth (DFW) ROC site who execute the protocols and make this type of study possible. In addition to giving credit to the EMS providers, the investigators are also deeply grateful to the conscientious data coordinators at the DFW ROC site for their exceptional focus and diligence in abstracting the data for this study.

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