Perishock Pause
An Independent Predictor of Survival From Out-of-Hospital Shockable Cardiac Arrest

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Background—Perishock pauses are pauses in chest compressions before and after defibrillatory shock. We examined the relationship between perishock pauses and survival to hospital discharge.

Methods and Results—We included out-of-hospital cardiac arrest patients in the Resuscitation Outcomes Consortium Epistry–Cardiac Arrest who suffered arrest between December 2005 and June 2007, presented with a shockable rhythm (ventricular fibrillation or pulseless ventricular tachycardia), and had cardiopulmonary resuscitation process data for at least 1 shock (n=815). We used multivariable logistic regression to determine the association between survival and perishock pauses. In an analysis adjusted for Utstein predictors of survival, the odds of survival were significantly lower for patients with preshock pause ≥20 seconds (odds ratio, 0.47; 95% confidence interval, 0.27 to 0.82) and perishock pause ≥40 seconds (odds ratio, 0.54; 95% confidence interval, 0.31 to 0.97) compared with patients with preshock pause <10 seconds and perishock pause <20 seconds. Postshock pause was not independently associated with a significant change in the odds of survival. Log-linear modeling depicted a decrease in survival to hospital discharge of 18% and 14% for every 5-second increase in both preshock and perishock pause interval (up to 40 and 50 seconds, respectively), with no significant association noted with changes in the postshock pause interval.

Conclusions—In patients with cardiac arrest presenting in a shockable rhythm, longer perishock and preshock pauses were independently associated with a decrease in survival to hospital discharge. The impact of preshock pause on survival suggests that refinement of automatic defibrillator software and paramedic education to minimize preshock pause delays may have a significant impact on survival. (Circulation. 2011;124:58-66.)

Key Words: cardiopulmonary resuscitation ▪ heart arrest ▪ resuscitation ▪ survival

Resuscitation from out-of-hospital cardiac arrest (OHCA) continues to challenge emergency medical services (EMS) systems.1,2 One key to improving survival may depend on the characteristic components of cardiopulmonary resuscitation (CPR). Cardiopulmonary resuscitation metrics such as chest compression fraction (proportion of time performing chest compressions during CPR), chest compression depth, compression rate, and chest recoil can potentially affect survival.3,4 Interruptions in chest compressions have also been associated with adverse outcomes.5–10 Therefore, the recently published 2010 American Heart Association guidelines stress the need to minimize interruptions in chest compressions.11 One important determinant of chest compression interruption is compulsory rhythm analysis and defibrillatory shock for shockable cardiac arrest. Defibrillator characteristics and rescuer actions can contribute to this interruption. This specific interruption in chest compressions before and after defibrillatory shock, called the perishock pause (Figure 1), may relate to outcome in a distinctive manner because of the critical transition between the electric and mechanical characteristics of the heart. As opposed to other interruptions in which the rhythm and mechanical status of the heart may not be expected to change, the goal of minimizing perishock pause is successful defibrillation, re-
time of organized rhythm, and ultimately resumption of spontaneous circulation. Although animal studies indicate a strong relationship between shorter perishock interruptions in chest compression and better outcomes,12,13 only a few clinical studies have evaluated the role of perishock pause with inconsistent results.14–16

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The relationship between perishock pause and outcome has important implications for care. If shorter perishock interruptions improve resuscitation outcome, then additional efforts should focus on minimizing these interruptions. These efforts may require improvements in defibrillator technology, better safety equipment for rescuers, or additional training to achieve improved rescuer performance. Thus, we undertook an investigation to determine the relationship between perishock pauses and survival to discharge in a large OHCA registry.

Methods

Setting and Design

The Resuscitation Outcomes Consortium (ROC) consists of 11 regional clinical centers across North America. The goal of these centers is to promote prehospital research in the areas of cardiac resuscitation and life-threatening trauma.17 Beginning in December 2005, the ROC prospectively collected cardiac arrest epidemiological data (ROC Epistry—Cardiac Arrest) on OHCA evaluated by participating agencies.18 Agencies participating in ROC captured electronic defibrillator CPR process data, including real-time measures of chest compression fraction, compression depth, and compression rate during cardiac arrest resuscitation. Five EMS agencies (Toronto, ON, Canada; Ottawa ON, Canada; Vancouver, BC, Canada; Pittsburgh, PA; Seattle/King County, Washington) participated in this study.

Study Sample

Between December 1, 2005, and June 30, 2007, patients eligible for this study included those who sustained OHCA with a first EMS shockable rhythm of ventricular fibrillation or pulseless ventricular tachycardia (VF/VT) for which CPR process data for at least 1 shock were obtained. The initial rhythm was determined to be VF/VT if the initial automatic external defibrillator analysis advised a shock or the rhythm was interpreted as VF/VT by the initial EMS provider and a shock was provided. We excluded patients who received public-access defibrillation (n = 16) before EMS arrival or were missing information on survival to hospital discharge (n = 8).

Measurement

We reviewed CPR process recordings from 815 resuscitations available from PhysioControl (n = 637), Phillips (n = 99), Zoll (n = 62), and other (n = 17) defibrillators. Real-time data were recorded after electrodes were applied to the patients’ chests. We assessed chest compression fraction, duration of preshock and postshock pauses, compression depth (Zoll and Philips, n = 77), and compression rate. Following the principles of uniform reporting of measured quality of CPR described by Kramer-Johansen et al.,19 preshock pause was defined as the time interval between chest compression cessation (as detected in the impedance channel waveform) and shock delivery. Postshock pause was defined as the time between shock delivery and chest compression resumption (as detected in the impedance channel waveform). Perishock pause was defined as the total preshock and postshock pause time. Trained data abstractors used the above specific definitions and manually abstracted preshock and postshock intervals from all available CPR process files up to 11 shocks. The study principal investigator (S.C.) reviewed a random sample of 20% of cases from each site to ensure the validity of the abstracted preshock and postshock pause intervals.
Individual shocks with missing values for length of pauses were included as long as there was at least 1 nonmissing pause length among the shocks considered. The primary outcome measure was survival to hospital discharge. The secondary outcome measure was return of spontaneous circulation (ROSC) at emergency department arrival.

Statistical Analysis
To assess whether these cases were subject to selection bias, we used descriptive statistics to compare all VF/VT episodes in our analysis with VF/VT episodes without ECG recordings from the 5 participating sites.

Multivariable logistic regression models were used to assess the association between preshock, postshock, and perishock pause and survival to hospital discharge. In an attempt to minimize the impact of confounding by other resuscitation variables, these models included pause information from only the first 3 shocks. Data from additional shocks (when applicable) were used in sensitivity analyses. For each patient, we used the longest preshock, postshock, or perishock pause among the number of shocks considered. One set of models examined the length of pauses as categories (10, 10 to 19, ≥20 seconds for preshock and postshock pauses; ≥20, 20 to 39, ≥40 seconds for perishock pauses); another set of models examined the length of pauses as a continuous variable (change presented as an increase in length by 5 seconds). Log-linearity of the continuous version of the variable, assessed with lowess graphs and fractional polynomials, was found to be appropriate for pauses up to 40 seconds for preshock and postshock pauses and for pauses up to 50 seconds for perishock pauses. We adjusted for recognized Utstein predictors of survival: age, sex, public location, witness status, bystander CPR, and time from 9–1–1 dispatch to first vehicle arrival. We also adjusted for site because of its strong association with outcome across ROC.

Table 1 displays baseline characteristics with VF/VT cases included and VF/VT cases excluded (owing to no ECG recordings available at the time of shock pause data abstraction). Compared with VF/VT cases without ECG recordings, included cases were more likely to be bystander witnessed (66.4% versus 60.2%; P < 0.001) and to receive bystander CPR (51.9% versus 40.4%; P < 0.001). Patient age and sex and episode characteristics (advanced life support on scene and EMS arrival time) were similar between groups.

Table 1. Patient and System Characteristics Comparing Cases Included in the Analysis and Those Excluded Owing to a Lack of Available Cardiopulmonary Resuscitation Process Files

<table>
<thead>
<tr>
<th>Study Sample</th>
<th>VF/VT Not in Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>815</td>
</tr>
<tr>
<td>Mean (SD) age, y</td>
<td>63.8 (15.3)</td>
</tr>
<tr>
<td>Women, %</td>
<td>21.1</td>
</tr>
<tr>
<td>Public location, %</td>
<td>33.5</td>
</tr>
<tr>
<td>Bystander witnessed, %</td>
<td>66.4</td>
</tr>
<tr>
<td>Bystander CPR, %*</td>
<td>51.9</td>
</tr>
<tr>
<td>Cardiac cause, %</td>
<td>96.9</td>
</tr>
<tr>
<td>ALS on scene, %</td>
<td>92.5</td>
</tr>
<tr>
<td>Mean arrival time, min</td>
<td>5.9</td>
</tr>
</tbody>
</table>

VF/VT indicates ventricular fibrillation/ventricular tachycardia; CPR, cardiopulmonary resuscitation; and ALS, advanced life support.

*Significant at P < 0.001.

Results
Of the 11,552 treated cardiac arrest cases in the 5 participating sites between December 2005 and June 2007, there were 2,743 with an initial rhythm of VF/VT (Figure 2). In 815 cases, an electronic ECG was available for research staff to calculate preshock and postshock pause data. A total of 3,756 shocks were delivered with 2,313 preshock pause and 2,447 postshock pause intervals available for analysis. Table 1 displays baseline characteristics with VF/VT cases included and VF/VT cases excluded (owing to no ECG recordings available at the time of shock pause data abstraction). Compared with VF/VT cases without ECG recordings, included cases were more likely to be bystander witnessed (66.4% versus 60.2%; P < 0.001) and to receive bystander CPR (51.9% versus 40.4%; P < 0.001). Patient age and sex and episode characteristics (advanced life support on scene and EMS arrival time) were similar between groups. Table 2 displays CPR process data for those with and without ECG recordings. The median preshock pause in the study sample was 15.6 seconds (0 to 107 seconds), and the median postshock pause was 8.3 seconds (0 to 220 seconds). Mean compression rate, chest compression fraction, and compres-
Cheskes et al. Perishock Pause Predicts Survival From VF/VT

Table 2. Cardiopulmonary Resuscitation Process Data in the Study Sample Compared With Those Not in the Study Sample

<table>
<thead>
<tr>
<th>Study Sample</th>
<th>VF/VT Not in Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>815</td>
</tr>
<tr>
<td>Mean (SD) CPR process minutes, n</td>
<td>0.5 (2.1)</td>
</tr>
<tr>
<td>Mean (SD) compression rate, n/min</td>
<td>109.7  (18.7)</td>
</tr>
<tr>
<td>Compression rate out of range, %</td>
<td>31.0</td>
</tr>
<tr>
<td>Mean (SD) CPR fraction</td>
<td>0.65 (0.18)</td>
</tr>
<tr>
<td>CPR fraction out of range, %†</td>
<td>18.3</td>
</tr>
<tr>
<td>Mean (SD) compression depth, mm</td>
<td>38.4 (11.0)</td>
</tr>
<tr>
<td>Preshock pause (min, 25, med, 75, max), s</td>
<td>170, 3.8, 8.3, 16, 220</td>
</tr>
<tr>
<td>Postshock pause (min, 25, med, 75, max), s</td>
<td>20, 3.8, 5.5, 10, 20.3, 32</td>
</tr>
</tbody>
</table>

VF/VT indicates ventricular fibrillation/ventricular tachycardia; CPR, cardiopulmonary resuscitation; min, minimum; 25, 25th percentile; med, median; 75, 75th percentile; and max, maximum. Mean values for compression rate, CPR fraction, compression depth, and median shock pause durations are for all 1-minute epochs studied.

*a Compression rate out of range if >40% of individual 1-minute epochs had a rate <90 or >130 compressions per minute.
†CPR fraction out of range if >40% of individual epochs had a CPR fraction <0.6.

Discussion

To the best of our knowledge, this is the only out-of-hospital study to date examining the relationship between perishock pause and survival to hospital discharge from shockable cardiac arrest. Unadjusted data showed a benefit to survival for patients with preshock pauses <20 seconds and perishock pauses <40 seconds. When adjusted for relevant covariates, a preshock pause ≥20 seconds (OR, 0.47; 95% CI, 0.27 to 0.82) and perishock pause ≥40 seconds (OR, 0.54; 95% CI, 0.31 to 0.97) compared with patients with preshock pause <10 seconds and perishock pause <20 seconds. Postshock pause was not independently associated with a significant change in the odds of ROSC in the emergency department using the same model.

Table 5 presents adjusted ORs for all covariates in the model that examined the relationship between categorical preshock and postshock pause variables and survival to hospital discharge. The odds of survival were significantly lower for patients with preshock pause ≥20 seconds (OR, 0.47; 95% CI, 0.27 to 0.82) and perishock pause ≥40 seconds (OR, 0.54; 95% CI, 0.31 to 0.97) compared with patients with preshock pause <10 seconds and perishock pause <20 seconds. In contrast, postshock pause was not independently associated with a significant change in the odds of survival. In addition to preshock and postshock pause, patient age, public location, witness status, and arrival time were also significantly associated (P<0.05) with survival to hospital discharge.

When modeled continuously, odds of surviving were 18% lower (OR, 0.82; 95% CI, 0.73 to 0.93) for every 5-second increase in preshock pause, 4% higher (OR, 1.04; 95% CI, 0.92 to 1.16) for every 5-second increase in postshock pause, and 14% lower (OR, 0.86; 95% CI, 0.77 to 0.95) for every 5-second increase in perishock pause.

Postshock, and perishock pauses were shorter among survivors than nonsurvivors, whereas chest compression fraction and compression rate were similar for both survivors and nonsurvivors. The relatively high chest compression fractions noted in our study may reflect the greater number of cases originating from EMS systems that perform continuous compressions (64%) with no interruption of CPR for ventilations as opposed to standard 30:2 compression/ventilation CPR (36%). This technique minimizes hands-off time and therefore maximizes chest compression fraction. Compression depth was greater for survivors compared with nonsurvivors, but data were available for only 77 patients.

In an adjusted model exploring the relationship between shock pause interval and ROSC in the emergency department, the odds of ROSC were significantly lower for patients with preshock pause ≥20 seconds (OR, 0.37; 95% CI, 0.20 to 0.71) and perishock pause ≥40 seconds (OR, 0.52; 95% CI, 0.27 to 0.97) compared with patients with preshock pause <10 seconds and perishock pause <20 seconds. Postshock pause was not independently associated with a significant change in the odds of ROSC in the emergency department using the same model.
findings are consistent with previously published data that relate preshock pause to ROSC. Edelson et al.\(^\text{14}\) were able to demonstrate a relationship between shock termination of VF and shorter preshock pause intervals in a study of in-hospital cardiac arrest and OHCA. A logistic regression analysis demonstrated that successful defibrillation was associated with shorter preshock pauses (OR, 1.86 for every 5-second decrease in preshock pause) and higher compression depth during the 30 seconds of CPR before the preshock pause. Given that survival to discharge cannot occur without successful termination of VF, we consider these findings consistent with our own findings of an 18% decrease in survival to hospital discharge for every 5-second increase in preshock pause length. We also noted a difference in compression depth between survivors and nonsurvivors, with survivors having deeper compressions (Table 4), although we were limited by a smaller number of cases with compression depth

### Table 3. Survival to Hospital Discharge as a Function of Maximum\(^\ast\) Shock Pause

<table>
<thead>
<tr>
<th>Preshock pause, s</th>
<th>Survival, %</th>
<th>(\geq 20)</th>
<th>(\geq 30)</th>
<th>(\geq 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>35.1</td>
<td>35.5</td>
<td>25.1</td>
<td>0.02</td>
</tr>
<tr>
<td>(\geq 20)</td>
<td></td>
<td></td>
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</table>

\(^\ast\)Limited to first 3 shocks.

### Figure 3. Plot of average perishock pause intervals by shock number. Manual indicates defibrillating shock delivered by a manual defibrillator or a defibrillator with automatic capabilities set to manual mode wherein the timing of shock delivery is fully operator dependent; AED, defibrillating shock delivered by an automated external defibrillator requiring a minimum analytic period before shock delivery.

### Table 4. Univariate Comparison of Cardiopulmonary Resuscitation Process Measures Between Survivors and Nonsurvivors

<table>
<thead>
<tr>
<th></th>
<th>Survivors</th>
<th>Nonsurvivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>226</td>
<td>589</td>
</tr>
<tr>
<td>Median preshock pause (min, max), s</td>
<td>14.1 (0, 53)</td>
<td>16.0 (0, 107)</td>
</tr>
<tr>
<td>Median postshock pause (min, max), s</td>
<td>7.2 (0, 121)</td>
<td>9.0 (0, 220)</td>
</tr>
<tr>
<td>Median perishock pause (min, max), s</td>
<td>24.0 (0, 130)</td>
<td>27.0 (0, 159)</td>
</tr>
<tr>
<td>Median CPR fraction (min, max)</td>
<td>0.69 (0.06, 1.0)</td>
<td>0.69 (0.08, 1.0)</td>
</tr>
<tr>
<td>Median compression rate (min, max), n/min</td>
<td>110.9 (38.2, 149)</td>
<td>109.9 (50.4, 165.3)</td>
</tr>
<tr>
<td>Median compression depth (min, max), mm</td>
<td>42.6 (25.7, 60.1)</td>
<td>35.9 (16.0, 70.5)</td>
</tr>
</tbody>
</table>

CPR indicates cardiopulmonary resuscitation; min, minimum; and max, maximum.
Our surprising finding showing no significant relationship between postshock pause length and survival to hospital discharge appears to be supported by recent work by Berdowski et al., who showed that ventricular fibrillation recurred sooner and more frequently in patients who had immediate postshock chest compressions (shorter postshock pause) compared with those who received delayed postshock chest compressions (longer postshock pause). It was also study was only 21% compared with 53% in our study sample. These findings would suggest that improvements in CPR performance may have less impact on systems that have not been optimized for known predictors of resuscitation success.

Our median preshock pause interval of 15.6 seconds was consistent with that demonstrated by Kramer-Johansen23 (15 seconds), Pytte et al.24 (11 seconds in a manikin model), and Olasveengen et al.25 (17 seconds). Our data demonstrate a near-doubling of median preshock pause intervals in patients treated in the automatic mode compared with those treated in the manual mode. The elongated preshock pause interval noted in automatic-mode cases has been previously described by Snyder and Morgan26 and is required to allow the automatic external defibrillator sufficient time to analyze the patient’s underlying rhythm accurately, to charge the defibrillator, and to prompt the user to apply the appropriate action. Our median preshock pause may reflect the preponderance of cases in our study population in which the defibrillation was performed in the automatic (40%) as opposed to the manual (20%) mode. What remains to be determined is the duration of the “optimal” preshock pause interval to improve resuscitation success from OHCA. Based on the observations by Sell et al.23 and Yu et al.,21 it would appear that our EMS agencies had significant challenges in attaining the optimal preshock pause interval of 3 seconds noted in these studies. This observation may explain in part why we were unable to show an adjusted survival benefit for patients treated in the manual mode as opposed to the automated mode because the median manual preshock pause length of 10 seconds in our study was significantly greater than the optimal value. A number of potential solutions exist to optimize the preshock pause interval based on the software design of automatic external defibrillators and rescuer performance of CPR. Defibrillator software that permits underlying rhythm analysis during CPR and battery charging and delivery of a shock immediately at the end of the CPR interval could significantly decrease the preshock pause interval. Improved algorithms allowing earlier detection of shockable rhythms while working in the automated mode could also decrease the preshock pause time.

Although the Edelson et al.21 study noted a trend toward improved survival to hospital discharge in patients with shorter preshock pauses, it was limited by a small sample size. Sell et al.215 were able to determine a similar relationship between preshock and postshock pauses and the likelihood of ROSC in patients presenting in VF in a small study of patients suffering from OHCA. This study was consistent with our findings and those of Yu et al.,21 who demonstrated a decrease in ROSC with prolonged preshock pause intervals in a porcine model of cardiac arrest. The recently published randomized controlled trial AED Use in Out-of-Hospital Cardiac Arrest: A New Algorithm Named “One Shock Per Minute” (DEFI 2005),22 in which resuscitations using the 2000 AHA guidelines was compared with resuscitations using a minor modification of the 2005 AHA guidelines, found no difference in survival to hospital admission in patients with VP despite shortened pauses in CPR (including preshock and postshock pause) and improved overall hands-on time. Only automatic defibrillators, along with CPR assist devices, were used during the study period. An important difference between our study and DEFI 2005 appears to be the EMS response time to cardiac arrest. The DEFI 2005 study group reported a mean response time of 10.5 minutes compared with 5.9 minutes in our study population. In addition, the rate of bystander CPR in the DEFI

<table>
<thead>
<tr>
<th>Table 5. Logistic Regression Estimates Evaluating the Association Between Shock Pauses and Survival to Hospital Discharge</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Perishock Pause Predicts Survival From VF/VT</strong></td>
</tr>
<tr>
<td><strong>Episode, n</strong> 610 604</td>
</tr>
<tr>
<td><strong>Preshock and Postshock</strong></td>
</tr>
<tr>
<td><strong>Preshock &lt;10 s Reference</strong></td>
</tr>
<tr>
<td><strong>Preshock 10–19 s 0.78 (0.43–1.45) . . .</strong></td>
</tr>
<tr>
<td><strong>Preshock ≥20 s 0.47 (0.27–0.82) . . .</strong></td>
</tr>
<tr>
<td><strong>Postshock &lt;10 s Reference</strong></td>
</tr>
<tr>
<td><strong>Postshock 10–19 s 1.04 (0.65–1.66) . . .</strong></td>
</tr>
<tr>
<td><strong>Postshock ≥20 s 1.01 (0.60–1.68) . . .</strong></td>
</tr>
<tr>
<td><strong>Preshock &lt;20 s . . . Reference</strong></td>
</tr>
<tr>
<td><strong>Preshock 20–39 s . . . 0.73 (0.44–1.21) . . .</strong></td>
</tr>
<tr>
<td><strong>Preshock ≥40 s . . . 0.55 (0.31–0.97) . . .</strong></td>
</tr>
<tr>
<td><strong>Age (1-y increase) 0.97 (0.96–0.99) 0.97 (0.96–0.99)</strong></td>
</tr>
<tr>
<td><strong>Male 1.05 (0.65–1.69) 1.10 (0.69–1.77)</strong></td>
</tr>
<tr>
<td><strong>Public location 1.64 (1.10–2.46) 1.62 (1.08–2.42)</strong></td>
</tr>
<tr>
<td><strong>EMS witnessed 5.55 (2.12–14.6) 6.54 (2.47–17.4)</strong></td>
</tr>
<tr>
<td><strong>Bystander witnessed 1.83 (1.14–2.94) 1.87 (1.16–3.02)</strong></td>
</tr>
<tr>
<td><strong>Bystander CPR 1.52 (1.00–2.30) 1.51 (1.00–2.28)</strong></td>
</tr>
<tr>
<td><strong>Arrival time 0.90 (0.83–0.97) 0.90 (0.83–0.98)</strong></td>
</tr>
<tr>
<td><strong>Site A 0.29 (0.06–1.40) 0.31 (0.07–1.45)</strong></td>
</tr>
<tr>
<td><strong>Site B 0.43 (0.08–2.15) 0.41 (0.08–2.01)</strong></td>
</tr>
<tr>
<td><strong>Site C 1.85 (1.13–2.94) 1.62 (1.05–2.49)</strong></td>
</tr>
<tr>
<td><strong>Site D 0.32 (0.04–2.55) 0.28 (0.04–2.25)</strong></td>
</tr>
<tr>
<td><strong>Site E Reference</strong></td>
</tr>
</tbody>
</table>

EMS indicates emergency medical services; CPR, cardiopulmonary resuscitation; arrival time, time from 9-1-1 call dispatch to first vehicle arrival on scene. Episodes with missing variable data were excluded from the analysis. Values in parentheses are 95% confidence intervals.
proposed that the benefit of higher chest compression fraction may be offset by the detrimental occurrence of earlier recurrent VF in patients with shorter postshock pauses compared with those with longer postshock pauses. Our study was not able to address the issue of refibrillation accurately because the defibrillator software that eliminates CPR artifact and allows the provider an accurate assessment of the underlying rhythm was not universally available at the time of our study. Our results and those noted by Berdowski et al27 suggest that further study is required to better understand the optimal postshock pause interval and its relationship to resuscitation success.

We found no published data looking at the impact of multiple shocks to patients in VF and the impact of multiple shock pauses in the same patient. We developed our inferential modeling to account for multiple shocks. The present model reflects the perspective that in patients requiring multiple shock attempts during resuscitation, any single prolonged shock pause could have a deleterious impact on shock success, ROSC, and ultimately patient survival. Drawing on this hypothesis, we then used the longest shock pause intervals in determining the most beneficial preshock, postshock, and perishock intervals for evaluation in our logistic regression models. This technique allowed a more realistic analysis of the impact of cases in which a prolonged shock pause interval occurred as opposed to simply using the median of all shocks provided to a patient during resuscitation.

Our data reflected a gradual decrease in the length of all shock pause intervals with number of shocks. This is consistent with the dynamics of cardiac arrest management in which the initial components of resuscitation are more labor intensive (insertion of intravenous lines, airway management including endotracheal intubation, scene management, recognition of shockable rhythm in manual mode). Our findings are consistent with the findings of an observational full-scale simulation study by Hoyer et al28 in which drug administration before defibrillation resulted in significant increases in preshock pause intervals. The impact of interruptions in chest compressions caused by endotracheal intubation during cardiac arrest has been well documented by Wang et al.29 When occurring during the critical phase of shock administration, these delays may affect preshock pause interval and patient survival.

A potential relationship between chest compression fraction and perishock pause remains intriguing. We note that during any 1-minute epoch of cardiac resuscitation, the longer the perishock pause interval is, the lower the chest compression fraction is during that minute. Christenson et al30 were able to evaluate and demonstrate the incremental benefit of higher chest compression fraction on survival to hospital discharge for OHCA patients with an initial rhythm of VF or VT. The demonstrated association between survival and preshock pause interval may in fact be a surrogate marker for chest compression fraction during resuscitation. It is also possible that preshock pauses occur at a critical time in a resuscitation and may be the most important component of overall chest compression fraction.

Our study has several limitations. In performing our analysis, we considered a wide variety of models, including a risk-adjusted time related survival analysis, but lacked critical time element data (exact time of cardiac arrest as opposed to estimated times), which precluded such an analysis. Eligible cases in our study with electronic ECG recordings were compared with eligible cases without available electronic ECG recordings. Although there were no significant differences between the 2 groups with respect to patient characteristics and CPR process data, the rate of witnessed arrest and bystander CPR was higher in the study group and may reflect selection bias. We attempted to control for confounding by including important predictor variables in our logistic regression model; however, we did not control for non-Utstein variables, which may potentially confound the observed association including compression depth, compression rate, and chest compression fraction, as well as in-hospital care (hypothermia and coronary intervention). Because our data are taken from an observational registry, we can demonstrate only an association between perishock pause and survival to hospital discharge as opposed to a causal relationship. A randomized trial is required to evaluate a causal relationship, but this form of evaluation would pose major challenges both technically and ethically. Because our findings are consistent with findings noted in other human and animal studies, we suggest that further study is required to better understand the relationship between perishock pause and survival to hospital discharge.

Conclusions

Longer perishock pause intervals are independently associated with a decrease in survival to hospital discharge from OHCA caused by VF or VT. Preshock pause ≥20 seconds and perishock pause ≥40 seconds were significant predictors of lower survival from shockable cardiac arrest. The decrease in survival to hospital discharge was driven almost exclusively by prolongation of the perishock interval. The impact of perishock pause on survival has implications for EMS
educators and defibrillator manufacturers. Education and technology focusing on how to minimize preshock pauses safely may have a significant impact on survival outcomes. Further study is required to determine the optimal post-shock pause interval.

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Disclosures

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References

CLINICAL PERSPECTIVE

Interruptions in chest compressions during cardiopulmonary resuscitation are commonplace and known to be deleterious to resuscitation success. The 2010 American Heart Association guidelines on cardiopulmonary resuscitation recommend minimizing any interruptions in chest compressions to <10 seconds. Pauses occurring before and after defibrillatory shock, otherwise known as perishock pauses, have been shown to have a significant impact on both termination of ventricular fibrillation and return of spontaneous circulation. In this observational study from the Resuscitation Outcomes Consortium Cardiac Epistry, researchers have been able to demonstrate significant relationships between both preshock and perishock pause and survival to hospital discharge from shockable cardiac arrest. Interestingly, no significant relationship was noted between postshock pause and survival to hospital discharge. Although we recognize the study limitations, the implications of these findings are important for both defibrillator manufacturers and cardiopulmonary resuscitation educators. We suggest multiple methods of decreasing preshock pause, including increased use of manual-mode defibrillation for emergency medical service providers, improved algorithms for detecting ventricular fibrillation while working in automatic defibrillator mode, quicker charging of the defibrillator to allow earlier administration of a defibrillatory shock, and performance of cardiopulmonary resuscitation during the defibrillator charging phase, all with a goal of attaining an optimal preshock pause of <5 seconds. By minimizing the preshock pause interval, we may further improve the likelihood of resuscitation success from shockable cardiac arrest.
Perishock Pause: An Independent Predictor of Survival From Out-of-Hospital Shockable Cardiac Arrest
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