Outcome of out-of-hospital postcountershock asystole and pulseless electrical activity versus primary asystole and pulseless electrical activity

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Objective: In the prehospital setting, countershock terminates ventricular fibrillation (VF) in about 80% of cases. However, countershock is most commonly followed by asystole or pulseless electrical activity (PEA). The consequences of such a countershock outcome have not been well studied. The purpose of this investigation was to compare the outcome of prehospital VF victims shocked into asystole or PEA with that of patients whose first documented rhythm was asystole or PEA (primary asystole or PEA).


Setting: A municipal hospital with a catchment area of >200,000.

Patients: Consecutive adult patients with out-of-hospital nontraumatic cardiopulmonary arrest of cardiac origin. Patients found in VF who developed asystole or PEA after countershocks (group 1) and patients found in asystole or PEA (primary asystole or PEA) (group 2) were included if the reported downtime was <10 min.

Interventions: None.

Measurements and Results: Study end points included restoration of circulation (defined as a pulse for any duration), survival to hospital admission, and survival to hospital discharge. Ratios were determined, 95% confidence intervals were calculated, and observed differences were compared. For group 1 patients (n = 101), 61% of patients had a bystander-witnessed collapse and 34% received bystander cardiopulmonary resuscitation. For group 2 patients (n = 140), collapse was bystander witnessed in 71% and 45% received bystander cardiopulmonary resuscitation. These differences were not statistically significant. Restoration of circulation was significantly more frequent in group 2 than group 1 (42% vs. 16%, p < .001) as was survival to hospital admission (36% vs. 11%, p = .001). Survival to hospital discharge was greater in group 2 patients, but the difference failed to achieve statistical significance (10% vs. 3%, p = .62).

Conclusions: Countershock of prolongedVF followed by a nonperfusing rhythm has a worse prognosis than primary asystole or PEA and may be related to myocardial electrical injury. (Crit Care Med 2001; 29:2366–2370)

Key Words: heart arrest; sudden death; cardiopulmonary resuscitation; resuscitation; fibrillation; defibrillation; arrhythmia; survival; risk factors; coronary disease

Cardiovascular disease accounts for nearly 1 million deaths in the United States annually. Coronary artery disease is responsible for approximately 50% of these deaths and nearly 50% of deaths caused by coronary artery disease result from sudden cardiac deaths that occur outside the hospital (1). Early reports documented that the most common initial arrhythmias encountered in cases of out-of-hospital sudden cardiac deaths were ventricular fibrillation (VF) or ventricular tachycardia (2). Nonventricular rhythms were previously grouped under the broad designation of electromechanical dissociation or pulseless idioventricular rhythm and asystole. Such rhythms were encountered in approximately one-third of out-of-hospital cardiac arrest victims. The current classification refers to such cardiac arrest rhythms as “pulseless electrical activity” (PEA) and asystole. PEA and asystole are being reported with increasing frequency as the first electrocardiographic findings in out-of-hospital sudden cardiac deaths. This rhythm group now appears to represent the majority of patients in whom out-of-hospital resuscitation is attempted (3–5).

In most reports, the rate of survival when PEA or asystole is the initial documented cardiac arrest rhythm is poor and approximates 2% (2, 6). The survival rate for patients with PEA and asystole is generally believed to be so dismal that such patients have been excluded from models predicting survival from out-of-hospital cardiac arrest (7, 8). In contrast, VF is presumed to be a treatable cardiac arrest rhythm and as many as 50% of patients may survive to be discharged from the hospital (9, 10). Outcome appears to depend primarily on the availability of early defibrillation and early initiation of cardiopulmonary resuscitation (CPR) by lay bystanders. Successful electrical defibrillation or countershock can be defined as 1) termination of VF regardless of postshock rhythm, or 2) termination of VF followed by a spontaneous perfusing cardiac rhythm. Although countershock may be successful in terminating VF, these definitions have different clinical implications. Countershock of prolonged VF is followed by PEA or asystole in approximately 60% of patients (11, 12). Although generally believed to be more responsive to therapy than primary PEA and asystole, only 0% to 2% of postshock...
PEA and asystole patients survive to be discharged from the hospital (11). Defibrillation may therefore result in an untreatable rhythm. It has recently been demonstrated that the likelihood of such adverse postcountershock rhythm outcomes can be reduced when CPR precedes countershock of prolonged VF (13).

The purpose of this study was to compare the outcome of adult victims of out-of-hospital cardiac arrest initially found to have PEA or asystole to that of patients found in VF who developed PEA or asystole after one to three countershocks. To our knowledge, these two groups have not been previously compared.

METHODS

This study was approved by the Research Committee and Human Subjects Committee of our institution.

The study site is a 553-bed general municipal hospital located in southwestern Los Angeles County. The hospital catchment area is approximately 27 square miles with a census of approximately 210,000 based upon 1990 census data. The population of the catchment area ranges from lower to upper-middle income class and includes Caucasian, Hispanic, and Asian-Pacific Islander as the major ethnic groups.

The emergency medical service system incorporates a typical two-tiered response activated by a central, computer-assisted dispatch 911 network. First-responder engine company units are manned by firefighter–emergency medical technician-1 personnel with automated external defibrillators. Paramedics are certified in cardiac rhythm recognition, endotracheal intubation, defibrillation, and pharmacologic interventions used in advanced cardiac life support. Paramedics administer countershocks (when indicated), begin or continue CPR, perform endotracheal intubation, establish intravenous access, and initiate pharmacologic therapy before base station contact. Subsequent interventions are directed via radiotelemetry by certified nurses with emergency medicine faculty supervision.

Data were obtained from field rescue reports completed by paramedics, verbal reports from paramedics, which are included in nursing and physician notes, the emergency department cardiac arrest flow sheet, the emergency department record, and in-hospital records for all patients who survived to hospital admission. All data sources for each patient were abstracted by the investigators and entered into a database for later review. Data collection began on November 1, 1994, and extended to October 31, 1999.

The final data set included the patient’s age, sex, and past medical history; site of arrest (skilled nursing facility, home, or other); whether the arrest was witnessed; whether the patient received bystander CPR; initial arrest rhythm as determined by paramedics; number of countershocks; postcountershock rhythm; prehospital advanced cardiac life support interventions; resuscitative measures undertaken in the emergency department; disposition; and hospital course for admitted patients. The initial cardiac rhythm was that rhythm first determined by paramedics in the field. PEA was defined as an organized electrical rhythm (an electrocardiographic QRS complex) without palpable pulses. An arrest was determined to have been witnessed when collapse or loss of consciousness was observed by a bystander. Paramedic-witnessed arrests were those cases in which cardiopulmonary arrest occurred after arrival of paramedics. For unwitnessed arrests, downtime estimates were those estimated by a bystander or a nurse in instances of arrest in a skilled nursing facility.

Consecutive patients in whom resuscitative efforts were attempted by paramedics during the study period were considered for inclusion. Patients were excluded if <18 yrs of age, if arrest was the result of trauma, if drug therapy was administered via the endotracheal route, or if downtime (arrest to arrival of paramedics) was unknown or exceeded 10 min in duration. Certain patients were specifically excluded to minimize the likelihood that cardiac arrest was the result of primary respiratory arrest. Excluded patients included those for whom 1) the arrest was thought to be secondary to drug toxicity, i.e., intentional or accidental overdose; 2) witnesses reported choking before collapse or if a foreign object was observed in the airway during intubation attempts; 3) arrest was the result of drowning, electrocution, or hanging; and 4) arrest followed exposure to toxic gases or fumes. Two groups were defined within the population of eligible study patients: group 1—patients found in VF with an estimated arrest duration <10 mins who developed asystole or PEA after countershocks were delivered in the standard fashion, i.e., 200, 300, then 360 J, if necessary; group 2—patients found in asystole or PEA with an estimated arrest duration <10 mins.

Primary study endpoints were restoration of spontaneous circulation (organized QRS complex with palpable pulses for any period of time), survival to hospital admission, and survival to hospital discharge. Rates for each of these endpoints were determined and 95% confidence intervals calculated. Differences between groups were compared using chi-square. A p value of <.05 was considered statistically significant. No adjustment was made for multiple comparisons.

RESULTS

During the 5-yr study period, 522 atrumatic arrests in patients >18 yrs of age were reviewed (age range 21–101 yrs). Of these, 294 (56%) met inclusion criteria. Ninety-three patients were excluded because they received only endotracheal drug therapy and an additional 135 were excluded because the time to therapy (“downtime”) exceeded 10 mins or was unknown. Eligible patients were nearly equally divided between those found in asystole or PEA with an estimated downtime of <10 mins and those found in VF. The distribution of eligible patients into study groups is shown diagrammatically in Figure 1. Paramedic-witnessed arrests were subsequently analyzed as a separate group.

Demographic information for the study groups is presented in Table 1. Significant differences were not observed be-
between groups with respect to mean age (postshock PEA/asystole group 64 ± 15 yrs, primary PEA/asystole group 67 ± 17 yrs). The male-to-female ratio was 75/25 in the postshock PEA/asystole group and 60/40 in the primary PEA/asystole patients. This 15% difference in group gender was statistically significant ($p = .016$). There were no significant differences in the frequency of chronic comorbid diseases between the groups. A significantly greater number of primary PEA/asystole arrests occurred in extended care facilities than in the postshock PEA/asystole group (29% vs. 12%, $p = .001$).

Outcome data for nonparamedic-witnessed arrests are presented in Table 2. A significantly greater number of patients found in PEA or asystole were resuscitated and survived to be admitted to the hospital when compared with patients who developed asystole or PEA after countershocks. Three times as many patients in the primary asystole or PEA group survived to hospital discharge. However, this difference failed to attain statistical significance. The sample size had a power of 0.80 to detect a 15% difference in survival to hospital discharge rate between the two groups. Outcomes for only bystander-witnessed arrests are presented in Table 3. For this subgroup of only witnessed arrests, patients found in asystole or PEA had a significantly higher resuscitation rate and a higher frequency of survival to hospital admission. In the VF group, patients who survived to hospital admission received a lower defibrillation energy dose than those who did not survive to hospital admission ($407 ± 304$ J vs. $635 ± 427$ J). However, this difference did not attain statistical significance ($p = .0905$).

Paramedics witnessed the cardiac arrest in 7% of group 1 patients and 19% of group 2 patients. Two of these patients in group 1 who had a paramedic witnessed arrest developed a perfusing rhythm (restoration of circulation) and survived to be admitted to the hospital. Seven of the 27 patients who had a paramedic witnessed arrest in group 2 had a palpable pulse restored (restoration of circulation) and three survived to be admitted to the hospital. None of the patients in either group whose arrest was witnessed by paramedics survived to hospital discharge.

### DISCUSSION

The findings of the present study suggest that patients found in PEA or asystole at the time resuscitative efforts are begun have a significantly higher rate of restoration of spontaneous circulation and survival to hospital admission than for patients found in VF who develop PEA or asystole after countershock (secondary PEA or asystole). Although the survival to discharge rate for primary PEA and asystole was twice that observed for patients found in VF, this difference did not achieve statistical significance possibly the result of the small sample of patients that composed this final outcome category. The reasons for these unexpected differences are not immediately clear, but are of obvious interest as the prevalence of PEA and asystole as the reported initial arrest rhythm is increasing and as interest is being refocused on the definition of successful defibrillation.

VF is a treatable rhythm and the time from VF onset to electrical defibrillation is the greatest determinant of survival. Survival from VF cardiac arrest declines by approximately 7% to 10% for each minute without defibrillation (7). Reported discharge rates for out-of-hospital sudden cardiac death caused by VF range from 3% to 33%, with the highest survival rates observed in two-tiered emergency response systems that incorporate early defibrillation (2). The majority of survivors are those found to be in VF by advanced rescuers and who develop a spontaneous perfusing rhythm after one to three countershocks at an escalating defibrillation energy dose, e.g., 200 J, 300 J, then 360 J, if necessary. The outcome of nonperfusing rhythms, namely PEA and asystole, following one or more countershocks has not been extensively studied. Based upon existing literature, we estimate that PEA or asystole follows VF is a treatable rhythm and the time from VF onset to electrical defibrillation is the greatest determinant of survival. Survival from VF cardiac arrest declines by approximately 7% to 10% for each minute without defibrillation (7). Reported discharge rates for out-of-hospital sudden cardiac death caused by VF range from 3% to 33%, with the highest survival rates observed in two-tiered emergency response systems that incorporate early defibrillation (2). The majority of survivors are those found to be in VF by advanced rescuers and who develop a spontaneous perfusing rhythm after one to three countershocks at an escalating defibrillation energy dose, e.g., 200 J, 300 J, then 360 J, if necessary. The outcome of nonperfusing rhythms, namely PEA and asystole, following one or more countershocks has not been extensively studied. Based upon existing literature, we estimate that PEA or asystole follows VF.
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stitution demonstrated a 70% prevalence of PEA or asystole as the initially documented arrest rhythm (5). A nearly identical rate has been reported in the city of San Francisco (14). In the setting of emergency medical services–witnessed cardiac arrest encompassing a 21-community cohort, the prevalence of PEA and asystole as the initial documented arrest rhythm was reported to be approximately 66% (15). Two retrospective studies indicate that primary PEA and asystole are not uniformly fatal and that patients with these rhythms contribute substantially to overall survival statistics (16, 17).

The mechanism for nonperfusing postshock rhythms has not been defined but may be the result of myocardial high-energy phosphate depletion that complicates prolonged fibrillation or the effect of the electrical shock itself on myocyte membrane integrity and transcellular ionic transport (18–20). This latter experimental observation has resulted in the investigation of newer waveforms for transthoracic defibrillation and a reevaluation of low-energy shocks for the termination of VF (21, 22). In this study, there was a trend toward lower energy doses in those VF patients who survived to hospital admission compared with those who did not. However, myocardial injury may be related to peak current, which is not routinely measured in out-of-hospital resuscitation attempts.

Reports of asystole or bradyarrhythmias at the onset of cardiac arrest during ambulatory electrocardiographic monitoring have not provided information regarding the etiology of these rhythms (23–25). Such patients typically have structural and ischemic heart disease similar to the population with VF cardiac arrest. Potential reversible causes for PEA have recently been reemphasized (26). However, the routine use of interventions to specifically manage a “reversible” etiology for PEA has not been shown to result in a meaningful difference in clinical outcome (27). This suggests that reversible causes are rarely encountered and that PEA and asystole represent primary cardiac arrest rhythms in the majority of cases in which they are encountered.

A possible explanation is that some patients found to have PEA or asystole as the first rhythm by advanced rescuers did not have a primary cardiac etiology underlying the arrest event. However, we attempted to minimize this possibility by excluding patients with a greater likelihood of primary respiratory arrest, e.g., suspected overdose or history of drug abuse, choking before collapse, etc. A second possible explanation is that patients, found in what was termed PEA, actually had pulses that were not detected by advanced rescuers. The demonstrated inability of lay rescuers to identify the presence or absence of a pulse in a timely manner has lead to recent changes in the instruction of basic life support to the lay public (28). However, advanced rescuers (i.e., paramedics) with extensive training and frequent utilization of this skill are capable of detecting pulses with an accuracy of 90% (29). In rare instances, VF can “masquerade” as asystole and it is possible that a small number of patients included in the primary asystole group may have had unrecognized VF (30). Typically VF that masquerades as asystole is of low amplitude and laboratory and clinical studies indicate that low amplitude VF rarely responds favorably to countershock (31–33).

Assuming that the above confounding factors did not substantially impact the allocation of patients to the two study groups, our study suggests that postcountershock PEA and asystole are less responsive to currently recommended therapy when compared with the same rhythms if encountered as the first documented rhythm in out-of-hospital cardiac arrest. This may be related to the metabolic demands of the fibrillating myocardium compared with that of the nonworking heart. Prior work has demonstrated that despite the absence of functional myocardial contractions during VF, myocytes remain metabolically active. The oxygen requirements of the fibrillating myocardium and the rate of loss of high-energy phosphate stores have been defined in in vivo and in isolated heart preparations. The loss of myocardial adenosine triphosphate and the increase in transmyocardial resistance over time would correlate with the decline in the rate of successful resuscitation as VF persists (18, 24). The metabolic demands of the nonbeating heart seen in the setting of typical PEA are substantially less than that of the fibrillating heart and the high-energy phosphate pool is likely to be less depleted in a nonworking heart subjected to same duration of contractile arrest as that of fibrillating heart (34–36). This may explain the difference in outcome between our study groups when only out-of-hospital arrests with an estimated arrest duration of ≤10 mins are compared. In addition, it is likely that electrical defibrillation is not a benign intervention. Myocardial injury following repeated countershocks is well recognized (19–21). In addition, the typical on-scene scenario when repeated countershocks are attempted necessitates the frequent interruption of CPR and myocardial perfusion, which may be more detrimental than previously thought (37).

This study has several limitations. Its retrospective design precluded the strict control of variables previously shown to be predictive of successful resuscitation, e.g., time to CPR, witnessed arrest, etc. In addition, our estimates of time to definitive care are, at best, conservative approximations based upon estimates made by bystanders when the arrest was actually witnessed. In those cases when the arrest was not directly witnessed, time to definitive care was estimated, when possible, by paramedics based upon the time when the patient was last seen or observed by a bystander. The reliability of such estimates has been questioned and was the basis for our decision to use a time interval of <10 mins rather than attempt to define an absolute time interval (14). Some patients whose actual collapse duration was ≤10 mins may have been excluded from the analysis. Although significant differences were observed between groups in the rate of restoration of circulation and survival to hospital admission, the survival to hospital discharge rate, although three-fold greater in the primary PEA/asystole group, did not reach statistical significance, probably because of the sample size available.
for analysis at this end point. The initial sample size was large enough to afford a power of 0.80 to detect a 15% change in survival to hospital discharge rate. In contrast to out-of-hospital care of cardiac arrest victims, in-hospital care for resuscitated victims of out-of-hospital care is not standardized and we made no attempt to determine whether specific interventions were employed with equal frequency in the defined groups.

Defibrillation after prolonged VF is usually “successful” in that it terminates VF. In this study, successful defibrillation with one to three shocks occurred 75% of the time. However, PEA or asystole after countershock had a worse proximate outcome than when PEA or asystole were the initially encountered arrest rhythms. The likelihood of such postshock outcomes has been shown to decrease if CPR of even a brief duration precedes the initial defibrillation attempt (13). Whether lower-energy, biphasic defibrillation waveforms will alter the rate of occurrence of postshock asystole or PEA awaits large clinical trials in the out-of-hospital sudden cardiac death population.

REFERENCES

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