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Survival in Out-of-Hospital Cardiac Arrests with Initial Asystole or Pulseless Electrical Activity and Subsequent Shockable Rhythms

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Abstract

Background—Non-shockable arrest rhythms (Pulseless Electrical Activity and Asystole) represent an increasing proportion of reported cases of out-of-hospital cardiac arrest (OHCA). The prognostic significance of conversion from non-shockable to shockable rhythms during the course of resuscitation remains unclear.

Objective—To evaluate whether out-of-hospital cardiac arrest survival with initially non-shockable arrest rhythms is improved with subsequent conversion to shockable rhythms.

Methods—Secondary analysis of data in Epistry – Cardiac Arrest, an epidemiologic registry maintained by the Resuscitation Outcomes Consortium (ROC). This analysis includes OHCA events from December 1, 2005 through May 31, 2007 contributed by six US and two Canadian sites. For all EMS-treated adult (18 and older) cardiac arrest patients who presented with non-shockable cardiac arrest, we compared survival to hospital discharge between patients who did develop a shockable rhythm and those who did not based on receipt of subsequent defibrillation. Missing data were handled using multiple imputation. Multivariable logistic regression was used to adjust for potentially confounding variables.

Results—A total of 6,556 EMS treated adult cardiac arrest cases presented in non-shockable rhythms. Survival to discharge in patients who converted to a shockable rhythm was 2.77% while

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Statement of Participation

Each of the above-named authors made substantial contributions to the design, analysis, and interpretation of this study and participated in the drafting of this manuscript.

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Conflict of Interest

None of the authors had potential conflicts of interest pertaining to the subjects of this manuscript.

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survival in those who did not was 2.72% ($p = 0.92$). After adjusting for confounders, conversion to a shockable rhythm was not associated with improved survival (OR 0.88, 95% CI: 0.60–1.30).

Conclusion—For OHCA patients presenting in PEA/Asystole, survival to hospital discharge was not associated with conversion to a shockable rhythm during EMS resuscitation efforts.

Keywords

Out-of-Hospital; Cardiac Arrest; Non-shockable Rhythms; Survival

Introduction

Every year it is estimated there are over 155,000 out-of-hospital cardiac arrests (OHCA) in the United States. (1) Historically, the relative success of defibrillation at correcting shockable forms of cardiac arrest has resulted in a strong emphasis on the treatment of patients with both ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT). In contrast, due to their poor prognoses both pulseless electrical activity (PEA) and asystole are often considered non-survivable rhythms. (1–5)

The nature of cardiac care and resuscitation has been shifting over the last 50 years and EMS systems have observed a steady decrease in the incidence of shockable rhythms (VF and pulseless VT) in cardiac arrest. As this decreasing incidence has not been consistently observed in bystander-treated cardiac arrest, the exact cause remains unclear. However, it may be related to changing risk factors for sudden cardiac arrest (SCA) as well as earlier recognition and intervention for acute coronary syndromes (ACS). (6–13)

In recent years, as increased emphasis has been placed on the delivery of high-quality cardiopulmonary resuscitation (CPR), gradually improving survival from non-shockable rhythms (PEA and asystole) has been observed. (14–16) Current practice suggests that treatment of non-shockable rhythms should focus on increasing cardiac muscle perfusion and myocardial tissue excitability with CPR to encourage fibrillation which has a reasonably effective treatment – defibrillation. Similarly it is believed that converting from non-shockable rhythms to shockable rhythms represents a favorable improvement in patient condition resulting in an increased probability of survival. (17)

Critical scientific evaluation has raised the question of whether or not current strategies for treatment are based upon a correct understanding of the underlying pathophysiology. In 2007, Hallstrom *et al.* noted a decreased odds ratio for survival of 0.18 ($p = 0.036$) for patients with subsequently shockable rhythms relative to those who did not convert to shockable rhythms. (18) Three subsequent studies of OHCA however reported contrary findings, all noting improved survival of patients who converted to shockable rhythms after initially presenting with non-shockable rhythms. (19–21) More recently, an in-hospital cardiac arrest study reported findings similar to those reported by Hallstrom *et al.* with higher survival in both PEA and asystole patients who never converted to shockable rhythms. (22)

This study was conducted to determine if survival to hospital discharge was improved by conversion to shockable rhythms among OHCA victims initially found in non-shockable rhythms within this population. Definitively answering this question will enable us to better understand the significance of rhythm conversions for patient prognosis and treatment planning in cardiac arrest.

Methods

Setting

The Resuscitation Outcomes Consortium (ROC) is a cooperative network of ten North American resuscitation research centers designed primarily to conduct large-scale randomized controlled trials in cardiac and trauma resuscitation.

The data for this analysis were drawn from the Epidemiologic Registry (“Epistry”) of cardiac arrests collected prospectively by the ROC network prior to initiation of any clinical trials. The participating sites for our analysis include five metropolitan regions within the United States (Birmingham, Alabama; Dallas-Fort Worth, Texas; Milwaukee, Wisconsin; Pittsburgh, Pennsylvania; and Portland, Oregon/Vancouver, Washington) as well as one statewide network (based in Falls City, Iowa) and two Canadian provincial networks (based in Vancouver, British Columbia and Ottawa, Ontario). Two ROC member sites (Seattle, Washington; and Toronto, Ontario) opted not to release their data for secondary analyses. (23–25)

Study Design

This study protocol was approved by the Institutional Review Board at the Oregon Health & Science University.

This study is a secondary analysis of prospectively collected data. All adult (aged 18 and up) patients of cardiac arrest who were treated by participating EMS response agencies in the above-described geographic areas between December 1, 2005 and May 31, 2007 were considered for this study. (23)

The investigational cohorts are classified with regard to their initial EMS-assessed cardiac arrest rhythm. AED-assessed non-shockable rhythm was combined with EMS monitor-identified asystole and pulseless electrical activity to form the non-shockable rhythm group which was subdivided into two observational cohorts.

Those patients converting to shockable rhythms were identified by the delivery of one or more shocks later in the course of EMS resuscitation and were assigned to the SHOCK cohort. The delivery of one or more shocks was used as a surrogate marker for conversion to a ventricular fibrillation or pulseless ventricular tachycardia rhythm. Conversely, the NO SHOCK cohort was composed of those cases remaining in non-shockable rhythms (i.e., asystole or pulseless electrical activity) defined as having received no subsequent shocks during the course of their resuscitation.

We excluded initial rhythms of AED-assessed shockable rhythm along with monitor-identified VF and VT from the analysis. Cases were also excluded if they were known to be related to serious traumatic injury or asphyxiation or if resuscitation was terminated prematurely due to family request or discovery of a Do Not Attempt Resuscitation (DNAR) order.

Variables & Measurements

The primary outcome of interest was survival to hospital discharge. Variables considered in the multivariable analysis included age, gender, public location of arrest, bystander witnessed arrests, bystander CPR, EMS witnessed arrests, and EMS response time. Because these important measurable confounders have been established by prior research they were included in the multivariable model *a priori* and variable selection methods were not

employed. (3, 10, 18–21, 26–28) We also included ROC site as a confounding variable to account for the regional variation in survival that has been previously reported. (24, 25, 29)

Statistical Analysis

Patient characteristics were summarized to compare the SHOCK and NO SHOCK groups. These comparisons and univariate associations between predictor variables and survival were determined using simple logistic regression.

To address missing data we used multiple imputation, which has been shown to produce less-biased estimates and preserve study power better than analysis of complete cases alone. (30–33) Ten imputations were performed, as this has been demonstrated to achieve a high degree of statistical efficiency in datasets with low proportions of missing values such as ours. (34) Imputations were performed using the SAS MI procedure. Additionally, a complete case analysis was performed as a sensitivity analysis of our imputation model.

Multiple logistic regression analysis was used to assess the relationship between conversion to a subsequent shockable rhythm and survival to hospital discharge after adjusting for confounding variables. Both univariate and multivariable analyses were performed for each imputed data set. These results were then analyzed using the SAS MIANALYZE procedure to create combined point estimates and confidence intervals that appropriately accounted for the variance within and between imputed datasets. All p-values were 2-sided and an alpha of 0.05 was used for determining statistical significance. All statistical analyses were conducted using SAS V 9.22 (SAS Institute Inc., Cary, NC, USA.).

Results

Figure 1 displays the derivation of the study sample illustrating how the cohort selection was made. There were a total of 6,556 cases meeting our inclusion criteria of which 1,238 were subsequently shocked and assigned to the SHOCK cohort while 5,318 received no shocks and were assigned to the NO SHOCK cohort. Survival outcomes were known for 1,228 of 1,238 of the SHOCK cohort and 5,260 of the 5,318 NO SHOCK cohort leaving an unknown outcome in 68 (1%) cases. Overall unadjusted survival in both groups was nearly identical at 2.77% and 2.72% respectively ($p = 0.92$). Table 1 displays the covariates and their respective distributions within each cohort. The leftmost column of this table also illustrates the proportion of missing values for each of the covariates in the study group. In total, 29% of the observations had one or more missing values and overall 4.5% of the variable values were missing.

Results of the univariate analyses of the covariates from the imputed as well as complete cases analyses are highlighted in Table 2. Receipt of subsequent shocks was not associated with unadjusted survival from cardiac arrest (OR: 1.01, 95% CI: 0.70–1.47). Public location of arrest, bystander witnessed arrest, EMS witnessed arrests and shorter EMS response intervals were associated with improved survival. Univariate analyses were suggestive of an association between survival and ROC site within this population however the association did not remain after controlling for other confounders.

The results from the multivariable analyses are displayed in Table 3 for both the imputed and complete cases. After controlling for confounders, receipt of subsequent shocks was not associated with survival from cardiac arrest (OR: 0.88, 95% CI: 0.60–1.30). Public location of arrest, bystander witnessed arrests, and EMS witnessed arrests remained independent predictors associated with improved survival. After controlling for confounders there was no longer an association between EMS response intervals and survival.

The sensitivity analysis by complete case analysis revealed marginal shifts of the point estimates for several confounding relationships with the inclusion of incomplete cases by multiple imputation. With the exception of a subtle adjustment and loss of statistical significance for ROC site 8, none of these shifts resulted in substantive changes of direction or statistical significance to the calculated associations.

Discussion

We found no statistically significant relationship between conversion from initially non-shockable rhythms to subsequent shockable rhythms and survival to hospital discharge. These findings remained unchanged whether the analysis was limited to only complete cases or broadened to include all eligible cases by using multiple imputation to handle missing values. The addition of multiple covariates to the model, known from prior studies to be significant confounders, also had no significant impact on our estimate of the effect of subsequent rhythm conversion on survival to hospital discharge. (18–21)

As mentioned earlier, other researchers have previously examined the probability of survival as it relates to rhythm conversion. Figure 2 compares our unadjusted results with those of the previous 5 papers published on the subject. This figure does not represent a formal meta-analysis but is provided to allow visual comparison of related findings. In 2007, Hallstrom *et al.* conducted a retrospective analysis of data collected during the ASPIRE trial in the US and Canada. Their findings contradicted the previously held belief that conversion to shockable rhythms represented an improved probability of survival. (18) Two subsequent studies published independently in 2008 by Herlitz *et al.* (19) (conducted in Sweden) and Kajino *et al.* (conducted in Japan) (20) demonstrated findings contrary to those reported by Hallstrom. (19, 20) The following year, Olasveengen *et al.* published an account of a study conducted in Norway. They also found that the chances for survival improved significantly for patients who converted to shockable rhythms. (21) Adding to the debate, in 2010, Meaney *et al.* published their findings from a cohort of in-hospital cardiac arrests and found a considerably higher survival in both PEA and asystole patients who never converted to shockable rhythms. This study also examined multiple outcomes and found consistent results whether the outcome measured was return of spontaneous circulation (ROSC), 24-hour survival, survival to hospital discharge, or favorable neurologic outcome. (22)

The lead authors on these four OHCA papers (Herlitz, Kajino, Olasveengen, and Hallstrom) subsequently collaborated in 2010 on a commentary published in the journal *Resuscitation* to discuss their conflicting findings. They agreed that for a variety of reasons, “the ‘true’ rates probably lie somewhere in between and will likely be center specific due to differing criteria for attempting CPR, different treatment protocols and response time differentials, and possibly due to different community practices such as use of beta-blockade”. (35) Our findings appear consistent with this proposition. Despite a relatively large sample size and multiple imputation to allow complete case ascertainment in our analyses, we were unable to detect any statistically significant difference in outcome between the two cohorts. One potential explanation may simply be that not all non-shockable arrests are alike. While some non-shockable arrest etiologies may benefit from conversion to a shockable rhythm, other etiologies may actually be harmed by this development. This hypothesis deserves further study.

One potential explanation for our findings may simply be that not all non-shockable arrests are alike. While some non-shockable arrest etiologies may benefit from conversion to a shockable rhythm, other etiologies may actually be harmed by this development.

Bystander CPR was not predictive of survival to hospital discharge in this study. Past studies have identified this as an important factor for survival although very few studies have examined this question exclusively in the non-shockable subset of cardiac arrests. Bystander CPR is an important predictor of survival when VF is the presenting rhythm. It may be less important when PEA and asystole are the presenting rhythms. (19, 36) This finding warrants further study so that we can better understand the underlying mechanisms and pathophysiology.

While the prognosis from non-shockable rhythms is not as positive as it is for initially shockable rhythms, patients presenting with these rhythms can be successfully resuscitated as noted in this study. Moreover, it does not appear that converting to shockable cardiac arrest rhythms is a reliable indicator of improving status, nor is the lack of this conversion a marker of poor prognosis. We suggest that it is important to give every patient found in nonshockable rhythms (barring extenuating circumstances) the benefit of the doubt and aggressively perform CPR and attempt resuscitation until reasonable ACLS care options have been exhausted. Conversion to shockable rhythms alone is not a strong enough indicator upon which to base treatment recommendations.

Limitations

Discussion of the limitations in the ROC Epistry data have been previously published. (6, 23–25, 29, 37–40) This dataset is believed to be a near-complete census of all conforming cardiac arrests however any cases missing from the record are not believed to affect differential ascertainment. An additional limitation was the possibility that EMS crews could have provided shocks to patients who never converted to shockable rhythms as a “last ditch” effort before terminating resuscitation or when as a “benefit of the doubt” when identification of the rhythm was in question. Without continuous ECG Rhythm analysis (unavailable in these data) we were unable to accurately quantify the magnitude of this potential misclassification bias. However, this bias is not anticipated to systematically raise or lower adjusted survival. Additionally, this form of bias would presumably also exist in the prior studies that also used subsequent shocks as a surrogate for rhythm conversion.

Another limitation of this study is that our survival data were limited to survival to hospital discharge. The ROC epistry did not collect information on neurologic status at the time of discharge, and thus it is possible that neurologic status differed between the two groups but was not detected by this study.

An important strength of our study is the diversity of the communities and EMS systems involved including differences in geography, EMS structure, and patient population characteristics. These features make our results comparable to the original Hallstrom paper.

Conclusions

We found no evidence to support the belief that conversion from non-shockable to shockable rhythms during the course of resuscitation from out-of-hospital cardiac arrest is associated with improved survival to hospital discharge. The prognostic implications of conversion to a shockable rhythm remain unclear and are in need of further study.

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These analyses were carried out by the investigators. Neither the Clinical Trials Center nor the Publications Committee of ROC take responsibility for the analyses and interpretation of results. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung and Blood Institute or the National Institutes of Health.

References

1. Rea TD, Eisenberg MS, Sinibaldi G, White RD. Incidence of EMS-treated out-of-hospital cardiac arrest in the united states. *Resuscitation*. 2004; 63(1):17–24. [PubMed: 15451582]
2. Hostler D, Roth RN. Pulseless electrical activity: Sign of life, or terminal rhythm? *Prehosp Emerg Care*. 2003; 7(2):286–90. [PubMed: 12710794]
3. Kämäräinen A, Virkkunen I, Yli-Hankala A, Silfvast T. Presumed futility in paramedic-treated out-of-hospital cardiac arrest: An utstein style analysis in tampere, finland. *Resuscitation*. 2007; 75(2): 235–43. [PubMed: 17553611]
4. Kuisma M, Jaara K. Unwitnessed out-of-hospital cardiac arrest: Is resuscitation worthwhile? *Ann Emerg Med*. 1997; 30(1):69–75. [PubMed: 9209229]
5. Vayrynen T, Kuisma M, Maatta T, Boyd J. Who survives from out-of-hospital pulseless electrical activity? *Resuscitation*. 2008; 76(2):207–13. [PubMed: 17804144]
6. Brooks SC, Schmicker RH, Rea TD, Aufderheide TP, Davis DP, Morrison LJ, et al. Out-of-hospital cardiac arrest frequency and survival: Evidence for temporal variability. *Resuscitation*. 2010; 81(2): 175–81. [PubMed: 19942338]
7. Bunch TJ, White RD. Trends in treated ventricular fibrillation in out-of-hospital cardiac arrest: Ischemic compared to non-ischemic heart disease. *Resuscitation*. 2005; 67(1):51–4. [PubMed: 16146670]
8. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. *New England Journal of Medicine*. 2002; 347(16):1242–7. [PubMed: 12393821]
9. Cobb LA, Fahrenbruch CE, Olsufka M, Copass MK. Changing incidence of out-of-hospital ventricular fibrillation, 1980–2000. *JAMA: the journal of the American Medical Association*. 2002; 288(23):3008–13. [PubMed: 12479765]
10. Kuisma M, Maatta T. Out-of-hospital cardiac arrests in helsinki: Utstein style reporting. *Heart*. 1996; 76(1):18–23. [PubMed: 8774321]
11. Parish DC, Chandra KMD, Dane FC. Success changes the problem: Why ventricular fibrillation is declining, why pulseless electrical activity is emerging, and what to do about it. *Resuscitation*. 2003; 58(1):31–5. [PubMed: 12867307]
12. Rea TD, Eisenberg MS, Becker LJ, Murray JA, Hearne T. Temporal trends in sudden cardiac arrest: A 25-year emergency medical services perspective. *Circulation*. 2003; 107(22):2780–5. [PubMed: 12756155]
13. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *New England Journal of Medicine*. 2000; 343(17):1206–9. [PubMed: 11071670]
14. Brooks SC, Schmicker RH, Rea TD, Aufderheide TP, Davis DP, Morrison LJ, et al. Out-of-hospital cardiac arrest frequency and survival: Evidence for temporal variability. *Resuscitation*. 2010; 81(2):175–81. [PubMed: 19942338]
15. Walters JH, Morley PT, Nolan JP. The role of hypothermia in post-cardiac arrest patients with return of spontaneous circulation: A systematic review. *Resuscitation*. 2011; 82(5):508–16. [PubMed: 21367510]
16. Grmec S, Strnad M, Podgorsek D. Comparison of the characteristics and outcome among patients suffering from out-of-hospital primary cardiac arrest and drowning victims in cardiac arrest. *International journal of emergency medicine*. 2009; 2(1):7–12. [PubMed: 19390911]

17. Leng CT, Berger RD, Calkins H, Lardo AC, Paradis NA, Halperin HR. Electrical induction of ventricular fibrillation for resuscitation from postcountershock pulseless and asystolic cardiac arrests. *Circulation*. 2001; 104(6):723–8. [PubMed: 11489782]
18. Hallstrom A, Rea TD, Mosesso VN Jr, Cobb LA, Anton AR, Van Ottingham L, et al. The relationship between shocks and survival in out-of-hospital cardiac arrest patients initially found in PEA or asystole. *Resuscitation*. 2007; 74(3):418–26. [PubMed: 17452069]
19. Herlitz J, Svensson L, Engdahl J, Silfverstolpe J. Characteristics and outcome in out-of-hospital cardiac arrest when patients are found in a non-shockable rhythm. *Resuscitation*. 2008; 76(1):31–6. [PubMed: 17709164]
20. Kajino K, Iwami T, Daya M, Nishiuchi T, Hayashi Y, Ikeuchi H, et al. Subsequent ventricular fibrillation and survival in out-of-hospital cardiac arrests presenting with PEA or asystole. *Resuscitation*. 2008; 79(1):34–40. [PubMed: 18678438]
21. Olasveengen TM, Samdal M, Steen PA, Wik L, Sunde K. Progressing from initial non-shockable rhythms to a shockable rhythm is associated with improved outcome after out-of-hospital cardiac arrest. *Resuscitation*. 2009; 80(1):24–9. [PubMed: 19081664]
22. Meaney PA, Nadkarni VM, Kern KB, Indik JH, Halperin HR, Berg RA. Rhythms and outcomes of adult in-hospital cardiac arrest. *Crit Care Med*. 2010; 38(1):101–8. [PubMed: 19770741]
23. Morrison LJ, Nichol G, Rea TD, Christenson J, Callaway CW, Stephens S, et al. Rationale, development and implementation of the resuscitation outcomes consortium epistry-cardiac arrest. *Resuscitation*. 2008; 78(2):161–9. [PubMed: 18479802]
24. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA: the journal of the American Medical Association*. 2008; 300(12):1423–31. [PubMed: 18812533]
25. Zive D, Kowproicz K, Schmidt T, Stiell I, Sears G, Van Ottingham L, et al. Variation in out-of-hospital cardiac arrest resuscitation and transport practices in the resuscitation outcomes consortium: ROC epistry-cardiac arrest. *Resuscitation*. 2011; 82(3):277–84. [PubMed: 21159416]
26. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: The Utstein style. *Circulation*. 1991; 84(2):960–75. [PubMed: 1860248]
27. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: Update and simplification of the Utstein templates for resuscitation registries. *Circulation*. 2004; 110:3385–97. [PubMed: 15557386]
28. Roger VL, Go AS, Lloyd-Jones DM, Adams RJ, Berry JD, Brown TM, et al. Heart disease and stroke statistics--2011 update: A report from the American Heart Association. *Circulation*. 2011; 123(4):18–209.
29. Callaway CW, Schmicker R, Kampmeyer M, Powell J, Rea TD, Daya MR, et al. Receiving hospital characteristics associated with survival after out-of-hospital cardiac arrest. *Resuscitation*. 2010; 81(5):523–8.
30. van der Heijden, Geert JMG, Donders ART, Stijnen T, Moons KGM. Imputation of missing values is superior to complete case analysis and the missing-indicator method in multivariable diagnostic research: A clinical example. *J Clin Epidemiol*. 2006; 59(10):1102–9. [PubMed: 16980151]
31. Koopman L, van der Heijden, Geert JMG, Grobbee DE, Rovers MM. Comparison of methods of handling missing data in individual patient data meta-analyses: An empirical example on antibiotics in children with acute otitis media. *Am J Epidemiol*. 2008; 167(5):540–5. [PubMed: 18184640]
32. Collins LM, Schafer JL, Kam C. A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychol Methods*. 2001; 6(4):330–51. [PubMed: 11778676]
33. Newgard CD, Haukoos JS. Advanced statistics: Missing data in clinical research -- part 2: Multiple imputation. *Acad Emerg Med*. 2007; 14(7):669–78. [PubMed: 17595237]
34. Schafer J, Olsen M. Multiple imputation for multivariate missing-data problems: A data analyst's perspective. *Multivariate Behavioral Research*. 1998; 33(4):545–71.
35. Hallstrom AP, Herlitz J, Kajino K, Olasveengen TM. Treatment of asystole and PEA. *Resuscitation*. 2009; 80(9):975–6. [PubMed: 19581035]

36. Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: A systematic review and meta-analysis. *Circulation: Cardiovascular Quality and Outcomes*. 2010; 3(1):63–81. [PubMed: 20123673]
37. Bradley SM, Gabriel EE, Aufderheide TP, Barnes R, Christenson J, Davis DP, et al. Survival increases with CPR by emergency medical services before defibrillation of out-of-hospital ventricular fibrillation or ventricular tachycardia: Observations from the resuscitation outcomes consortium. *Resuscitation*. 2010; 81(2):155–62. [PubMed: 19969407]
38. Cheskes S, Schmicker RH, Christenson J, Salcido DD, Rea T, Powell J, et al. Perishock pause: An independent predictor of survival from out-of-hospital shockable cardiac arrest. *Circulation*. 2011; 124(1):58–66. [PubMed: 21690495]
39. Hostler D, Thomas EG, Emerson SS, Christenson J, Stiell IG, Rittenberger JC, et al. Increased survival after EMS witnessed cardiac arrest. observations from the resuscitation outcomes consortium (ROC) epistry cardiac arrest. *Resuscitation*. 2010; 81(7):826–30. [PubMed: 20403656]
40. Rea TD, Cook AJ, Stiell IG, Powell J, Bigham B, Callaway CW, et al. Predicting survival after out-of-hospital cardiac arrest: Role of the utstein data elements. *Ann Emerg Med*. 2010; 55(3): 249–57. [PubMed: 19944488]

Figure 1. Process of selection of cases for inclusion in analysis

Resuscitation attempted includes cases for which EMS personnel provided life support treatment and did not terminate their resuscitation for reasons of DNAR order or family request. Initial non-shockable rhythms include PEA and asystole. Subsequent shocks were a surrogate for conversion to secondary VF/VT. Final exclusions were made for age < 18, traumatic arrest, or arrest secondary to asphyxiation (drug overdose, drowning, hanging, etc.). n = number fitting each category; bold values indicate proportion of each parent category; parenthetical values indicate proportion of all cases.

Figure 2. Forest plot comparing these results to prior studies

Comparison of univariate point estimates and confidence intervals for related prior studies.

Hallstrom et al., Olasveengen et al., Meaney et al., and Thomas et al. studied survival to hospital discharge as an end point. Herlitz et al. studied the outcome of 1-month survival and Kajino et al. studied neurologically intact survival to hospital discharge as an end point.

Meaney et al. was a study on in-hospital cardiac arrest.

Table 1

Population characteristics

Covariates (Missing Proportion)	Shock n (%)	No Shock n (%)	p-value
Gender (0.1%)			
Male	813 (65.7%)	3,167 (59.6%)	<0.001 *
Female	425 (34.3%)	2,145 (40.4%)	<0.001 *
Age (0.0%)			
18–39	86 (6.9%)	462 (8.7%)	0.046 *
40–59	371 (30.0%)	1,511 (28.4%)	0.276
60–79	516 (41.7%)	2,210 (41.6%)	0.937
80+	265 (21.4%)	1,135 (21.3%)	0.961
Setting Characteristics			
Public Location (0.1%)	187 (15.1%)	538 (10.1%)	<0.001 *
Bystander Witnessed (20.0%)	526 (51.8%)	1,578 (37.3%)	<0.001 *
Bystander Resuscitation (12.6%)	371 (33.8%)	1,497 (32.3%)	0.360
EMS System Characteristics			
EMS Witnessed (0.0%)	103 (8.2%)	490 (9.2%)	0.323
Response	597 (49.9%)	2,722 (52.6%)	0.094
Survival to Discharge (1.0%)	34 (2.8%)	143 (2.7%)	0.923

Population characteristics of cases conforming to inclusion and exclusion criteria. Values are quantity and proportions with p-values generated by simple logistic regression. Parenthetical values in column 1 describe the proportion of observations in each group (n = 1,238 for SHOCK and 5,318 for NO SHOCK) who were missing each covariate.

* Indicates statistically significant differences between the populations.

Table 2

Results from univariate comparisons

	Imputed Cases OR (95% CI)	Complete Cases OR (95% CI)
Shocks Delivered	1.01 (0.70–1.47)	1.02 (0.69–1.49)
Male Gender	0.95 (0.69–1.30)	0.94 (0.69–1.27)
Age (10 Years)	0.93 (0.85–1.02)	0.93 (0.85 –1.02)
Bystander		
Public Location	1.89 (1.30–2.75)	2.19 (1.51–3.17)
Bystander Witnessed	2.13 (1.55–2.92)	2.64 (1.83–3.81)
Bystander Resuscitation	1.05 (0.73–1.50)	1.08 (0.76–1.52)
EMS-Witnessed	2.64 (1.77–3.92)	2.89 (2.00–4.18)
Response Interval (1 Minute)	0.94 (0.91–0.98)	0.88 (0.83–0.94)

Odds ratios for survival to hospital discharge in subsequently shocked versus not shocked cases generated by univariate logistic regression. Imputed cases included all adult cases of out-of-hospital cardiac arrest which were resuscitated by EMS without premature cessation of efforts or evidence of traumatic or asphyxiant etiology of arrest. Complete cases were those for which the value of all studied variables were known.

Table 3

Results from the multivariable analysis.

	Imputed Cases OR (95% CI)	Complete Cases OR (95% CI)
Shocks Delivered	0.88 (0.60–1.30)	0.89 (0.55–1.45)
Male Gender	0.4 (0.68–1.29)	0.71 (0.48–1.07)
Age (10 Years)	0.93 (0.85–1.02)	0.95 (0.84–1.07)
Bystander		
Public Location	1.65 (1.12–2.45)	2.99 (1.89–4.73)
Bystander Witnessed	1.86 (1.35–2.55)	2.70 (1.76–4.15)
Bystander Resuscitation	1.07 (0.72–1.59)	1.18 (0.78–1.78)
EMS-Witnessed	1.94 (0.96–3.92)	2.89 (2.00–4.18)
Response Interval (1 Minute)	0.98 (0.93–1.03)	0.98 (0.92–1.05)
ROC Sites		
Site 1 (reference)	1.00	1.00
Site 2	1.30 (0.71–2.38)	1.48 (0.68–3.24)
Site 3	0.95 (0.51–1.79)	0.94 (0.43–2.08)
Site 4	0.41 (0.12–1.46)	0.30 (0.04–2.37)
Site 5	0.87 (0.45–1.69)	0.66 (0.23–1.85)
Site 6	0.65 (0.36–1.17)	0.63 (0.29–1.33)
Site 7	0.89 (0.38–2.07)	0.61 (0.20–1.83)
Site 8	0.63 (0.34–1.16)	0.44 (0.20–0.97)

Odds ratios for survival to hospital discharge in subsequently shocked versus not shocked cases generated by multivariable logistic regression. Imputed cases included all adult cases of out-of-hospital cardiac arrest which were resuscitated by EMS without premature cessation of efforts or evidence of traumatic or asphyxiant etiology of arrest. Complete cases were those for which the value of all studied variables were known.