Predicting Survival After Out-of-Hospital Cardiac Arrest: Role of the Utstein Data Elements

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Study objective: Survival after out-of-hospital cardiac arrest depends on the links in the chain of survival. The Utstein elements are designed to assess these links and provide the basis for comparing outcomes within and across communities. We assess whether these measures sufficiently predict survival and explain outcome differences.

Methods: We used an observational, prospective data collection, case-series of adult persons with nontraumatic out-of-hospital cardiac arrest from December 1, 2005, through March 1, 2007, from the multisite, population-based Resuscitation Outcomes Consortium Epistry–Cardiac Arrest. We used logistic regression, receiver operating curves, and measures of variance to estimate the extent to which the Utstein elements predicted survival to hospital discharge and explained outcome variability overall and between 7 Resuscitation Outcomes Consortium sites. Analyses were conducted for all emergency medical services–treated cardiac arrests and for the subset of bystander-witnessed patient arrests because of presumed cardiac cause presenting with ventricular fibrillation or ventricular tachycardia.

Results: Survival was 7.8% overall (n=833/10,681) and varied from 4.6% to 14.7% across Resuscitation Outcomes Consortium sites. Among bystander-witnessed ventricular fibrillation or ventricular tachycardia, survival was 22.1% overall (n=323/1459) and varied from 12.5% to 41.0% across sites. The Utstein elements collectively predicted 72% of survival variability among all arrests and 40% of survival variability among bystander-witnessed ventricular fibrillation. The Utstein elements accounted for 43.6% of the between-site survival difference among all arrests and 22.3% of the between-site difference among the bystander-witnessed ventricular fibrillation subset.

Conclusion: The Utstein elements predict survival but account for only a modest portion of outcome variability overall and between Resuscitation Outcomes Consortium sites. The results underscore the need for ongoing investigation to better understand characteristics that influence cardiac arrest survival. [Ann Emerg Med. 2010;55:249-257.]

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Editor's Capsule Summary

What is already known on this topic

There are large differences among out-of-hospital care systems in reported survival-to-hospital discharge rates after out-of-hospital cardiac arrest.

What question this study addressed

Do the Utstein elements predict survival and explain these differences in outcome?

What this study adds to our knowledge

In this analysis of 10,681 adult out-of-hospital cardiac arrests in a population-based registry, the Utstein elements explained only a modest proportion of the variation in survival rates.

How this might change clinical practice

Clinical practice will not change, but further efforts to understand these variations are warranted because they may lead to a better understanding of ways to improve survival.

INTRODUCTION

Background

Out-of-hospital cardiac arrest claims hundreds of thousands of lives each year in North America.[1] Hence, improving survival from cardiac arrest provides a meaningful opportunity to improve public health. For example, survival after ventricular fibrillation cardiac arrest ranges from 3% to more than 40%, depending on the community. Such variability suggests the potential to save thousands of additional lives if we can fully understand patient, circumstance, or care characteristics that critically influence prognosis.[2,3] This appreciation has produced the framework of resuscitation care termed "the links in the chain of survival," which include early emergency activation, early cardiopulmonary resuscitation (CPR), early defibrillation, and timely and appropriate advanced care.[4] Guidelines have provided core measures designed to assess the links in the chain of survival. These measures, termed the *Utstein data elements*, provide the basis for evaluating and comparing care and outcomes within and across communities.[5]

Importance

The extent to which these Utstein measures predict survival and account for outcome differences is not well studied. If such measures incompletely predict survival, the implications are that other unmeasured patient, circumstance, or care characteristics importantly influence resuscitation outcomes and would indicate a need for additional investigation to identify and measure outcome predictors.[6] This understanding can, in turn, directly guide efforts to improve resuscitation.

Goals of This Investigation

We used data from the Resuscitation Outcomes Consortium Epistry–Cardiac Arrest, an observational epidemiologic registry of out-of-hospital cardiac arrests, to determine the extent to which the Utstein data elements predict survival after out-of-hospital cardiac arrest and whether these data elements account for survival differences across participating Resuscitation Outcomes Consortium sites overall and among the clinical subset with bystander-witnessed ventricular fibrillation.[7] We specifically focused on this latter clinical subset, given that each of the Utstein elements can influence outcome in bystander-witnessed ventricular fibrillation or ventricular tachycardia. Hence, this clinical subset is the most relevant group designed to compare and contrast system performance.[5] We hypothesized that the Utstein data elements predict survival to hospital discharge but explain only a portion of survival variation overall and across sites participating in the Resuscitation Outcomes Consortium.

MATERIALS AND METHODS

Study Design, Setting, and Selection of Participants

This investigation is an observational, prospective data collection, case series of all persons older than 20 years and with nontraumatic out-of-hospital cardiac arrest from December 1, 2005, through March 1, 2007, who received attempted resuscitation (treatment) by organized emergency medical services (EMS) among 7 sites participating in the Resuscitation Outcomes Consortium. The Resuscitation Outcomes Consortium is an out-of-hospital emergency care clinical trials network composed of 11 sites from Canada and the United States.[8] Treated cardiac arrest was defined by attempts at external defibrillation (by layperson or EMS personnel) or chest compressions by organized EMS personnel. The Resuscitation Outcomes Consortium Epistry–Cardiac Arrest includes subjects with arrest regardless of nontraumatic cause and so includes arrests attributed to drowning, electrocution, overdose, and bleeding.[7] Given the scientific focus of this investigation, we a priori restricted the analysis to the 7 sites in which each of the Utstein data elements was missing in less than 10% of cases. The 7 sites were composed of 3 Canadian and 4 US sites, with a combined population of 17.7 million persons. Appropriate institutional review boards for each site approved the study.[7]

Methods of Measurement and Data Collection and Processing

In developing and implementing the Resuscitation Outcomes Consortium Epistry, investigators conducted a broad English-language literature review, using a broad search strategy of the databases MEDLINE, EMBASE, CINAHL, and Health Star publications from 1996 to 2004.[7] Using the search results, a multidisciplinary working group with representatives from each Resuscitation Outcomes Consortium site selected variables and developed consensus definitions and response options. The process incorporated published relevant information from the National EMS Information and Utstein templates for cardiac arrest reporting.[5] The process resulted in a common manual of operations and singular data abstraction form used by all sites in the Resuscitation Outcomes Consortium Epistry–Cardiac Arrest. A variety of approaches was used to assess and help ensure case capture and data consistency. For each site, agency-specific enrollment counts for each month were compared with cumulative averages to identify potential outlier ascertainment periods that could be reassessed for missed cases. In addition to the use of a common abstraction form and manual of operations, all sites underwent external audits by the Data Coordinating Center, whereby selected cases were reviewed and abstracted to validate classification. Range checks and basic logic were embedded into the electronic data entry used by all sites.

The dispatch and EMS reports, as well as the hospital record (for patients reaching the hospital), were reviewed and abstracted using a uniform abstraction form. The Resuscitation Outcomes Consortium data elements included information about patient characteristics (age, sex, and arrest cause), event circumstances (witness status, location, arrest before or after EMS arrival), presenting rhythm, care (bystander CPR status and EMS response intervals), Resuscitation Outcomes Consortium site, and the outcome (discharged alive from the hospital). Cardiac arrest was presumed to be related to cardiac cause if no other obvious cause (ie, drowning, bleeding, or overdose) was identified according to review or source information. This information was provided to the Data Coordinating Center in a deidentified manner.

Outcome Measures

The primary outcome was survival to hospital discharge.

Primary Data Analysis

In accordance with the Utstein template for cardiac arrest reporting, analyses were performed for all nontraumatic EMS-treated cardiac arrest and for the subset of bystander-witnessed patients with arrest because of presumed cardiac cause who presented with an initial rhythm of ventricular fibrillation or ventricular tachycardia.[5] We used descriptive statistics to assess the distribution of the Utstein data elements and used logistic regression to assess the univariate association between individual Utstein elements and survival to hospital discharge.

We used multivariable logistic regression to assess the collective predictability of the Utstein data elements among all EMS-treated arrests and bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause. We generated receiver operating characteristic curves with the regression models. The area under the curve could vary from 0.5 (no prediction) to 1.0 (perfect prediction).[9] The final quantitative measure of prediction associated with the collective Utstein data elements were calculated as ([the area under the curve−0.5]/0.5). The variables included were core Utstein data elements and chosen a priori. We performed 2 analyses when assessing the all-rhythm prediction of the Utstein elements, one with only initial rhythm and one with all the Utstein data elements, including initial rhythm to help assess the extent to which the initial rhythm influenced the predictability of the Utstein data elements. The models included age, sex, arrest cause, witness status, location of arrest, bystander CPR, whether the arrest occurred before EMS arrival, the initial presenting rhythm, and EMS response interval. We also assessed whether models that included an interaction between bystander CPR and EMS response interval improved the fit of the data with a χ^2 score test because previous research has reported that the benefit of bystander CPR depends on EMS response interval.[10]

We performed a single multivariable analysis in the model restricted to bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause. The variables included were age, sex, location of arrest, bystander CPR, and EMS response interval. In the logistic models, age and EMS response intervals were modeled as continuous variables. All other covariates were modeled as categorical variables. Subjects with one or more missing covariates were dropped from the multivariable models.

To visually assess the proportion of between-site variability explained by the Utstein data elements, we used logistic regression to determine the association between site and survival to hospital discharge. We plotted the resulting odds ratios (OR) and 95% confidence intervals (CIs) associated with site by using the site with the lowest survival as the reference group. Sites B through G were ordered according to increasing survival. An initial model included only site, whereas a second model contained site plus all the Utstein data elements used to generate the receiver operating characteristic curves. If Utstein data elements explained all of the between-site variability, then the ORs associated with site from the initial model would be attenuated to 1 in the full model that included site along with all of the Utstein elements. We also calculated an ad hoc quantitative assessment of the between-site variability explained by the Utstein data elements by calculating a variance estimate of the difference between estimated log OR of sites for a given model,

$$V_\beta = \sum_{j=1}^{5} \left(\hat{\beta}_j\right)^2 / 5$$

where $\hat{\beta}_j$ is the log OR of site j (j=1, . . . ,5) from logistic model $\text{logit}(Y_i) = \beta_0 + \beta_1 SiteB_i + \beta_2 SiteC_i + \beta_3 SiteD_i + \beta_4 SiteE_i + \beta_5 SiteG_i + \cdots$ Therefore to estimate the explained between-site variability, we calculated $(V_{\beta O} - V_{\beta P})/V_{\beta O}$ where $V_{\beta O}$ is the variance of the log ORs of the site variable from the model without the Utstein data elements and $V_{\beta P}$ is the variance of the log ORs of site with the Utstein data elements.

In a sensitivity analysis, we applied generalized linear mixed-effect models to take into account potential correlation within EMS agency. All P values were 2 sided and based on the χ^2 score statistic, except for the area under the curve CIs, which assumed the Mann-Whitney rank test. All 95% CIs were based on the Wald statistic. Statistical analyses were performed with

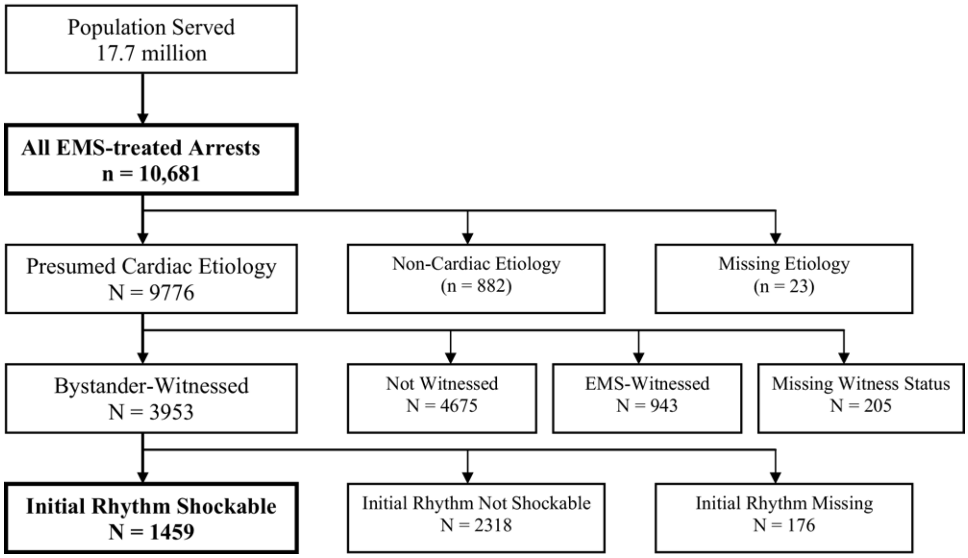

Figure 1. Utstein flow diagram of study subjects.

R, version 2.9.0, and R packages ROCR, SPLINES, and HMISC.[11-13]

RESULTS

During the 16 months of observation, 10,681 persons experienced cardiac arrest and received attempted EMS resuscitation (Figure 1). Of these, 23.0% (2,456/10,681) presented with an initial rhythm of ventricular fibrillation or ventricular tachycardia, and 13.7% (1,459/10,681) were citizen bystander–witnessed ventricular fibrillation or ventricular tachycardia arrest because of presumed cardiac cause. A total of 9.5% (1,013/10,681) of all EMS-treated arrests and 3.2% (47/1,459) of bystander-witnessed ventricular fibrillation or ventricular tachycardia arrests because of presumed cardiac cause were missing information on one or more covariates and so were dropped from the multivariable analyses. Among those missing covariate information so excluded from the multivariable analysis, survival was 11.1% (112/1,013) among all EMS-treated arrests and 12.8% (6/47) among those with bystander-witnessed ventricular fibrillation or ventricular tachycardia. Among the sites not included in this investigation because the Utstein elements were missing in greater than 10%, survival was 6.8% (162/2,359) from all-rhythm arrest.

The Table presents the distribution of patient, circumstance, and care characteristics and their univariate associations with survival in all EMS-treated arrests and among those with bystander-witnessed ventricular fibrillation arrest or ventricular tachycardia because of presumed cardiac cause. The majority of cardiac arrests occurred among men, were of presumed cardiac cause, and took place in the home. Approximately half of all arrests were witnessed and a third of all arrest patients received bystander CPR before EMS arrival. The distribution of the Utstein data elements varied significantly according to site: proportion of men ranged from 58.7% to 68.8%, proportion that occurred in a public location ranged from 13.7% to 17.9%, proportion who received bystander CPR ranged from 20.4% to 48%, the proportion with an EMS response less than 4 minutes ranged from 13.9% to 65.7%, and the proportion who presented with an initial shockable rhythm ranged from 19.5% to 28.2%. Survival to hospital discharge for all EMS-treated cardiac arrest was 7.8% overall (833/10,681) and varied from 4.6% to 14.7% across the 7 sites. Among bystander-witnessed ventricular fibrillation arrest or ventricular tachycardia because of presumed cardiac cause, survival was 22.1% overall (n=323/1,460) and varied from 12.5% to 41.0% across the 7 sites.

Logistic regression models that included the Utstein data elements significantly improved the fit of the data for all EMS-treated arrests and bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause compared with adjusting for site alone (both models with χ^2 $P<.001$). The addition of an interaction term between bystander CPR and EMS response interval did not improve the fit of the model (χ^2 $P=.78$) and so was not included in subsequent models. Figure 2A and B presents the receiver operating characteristic curves generated from logistic regression models that include the Utstein data elements for all EMS-treated arrest and bystander-witnessed ventricular fibrillation or ventricular tachycardia arrest because of presumed cardiac cause. Collectively, the Utstein data elements predicted 0.86 of the area under the curve, or approximately 72% of survival variability among all EMS-treated arrests (Figure 2A). However, the initial rhythm alone accounted for a large portion (66%) of this variability. When restricted to the primary Utstein comparison group of bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause, the Utstein data elements collectively predicted 0.70 of the area under the curve, or approximately 40% of survival variability (Figure 2B). Within individual sites, the variability predicted

Table. Distribution and univariate outcome associations of cardiac arrest characteristics.*

	All EMS-Treated OHCA			Bystander-Witnessed VT/VF OHCA Because of Presumed Cardiac Cause		
		Survive to Discharge			Survive to Discharge	
Characteristics	**N**	**(%)**	**OR (95% CI)**	**N**	**%**	**OR (95% CI)**
Total, No.	10,681	7.8		1,459	22.1	
Age, y, No. (%)						
20–39	665 (6.2)	9.0	2.12 (1.56–2.88)	66 (4.5)	34.8	3.50 (1.94–6.29)
40–59	2,858 (26.8)	10.4	2.49 (2.05–3.03)	478 (32.8)	26.6	2.37 (1.65–3.39)
60–74	3,304 (30.9)	9.3	2.20 (1.82–2.67)	538 (36.9)	22.9	1.94 (1.35–2.78)
≥75	3,854 (36.1)	4.5	1.0	377 (25.8)	13.3	1.0
Age, y, median (IQR)	69 (55, 80)		0.98 (0.98–0.99)	65 (54–76)		0.97 (0.96–0.98)
Nonsurvivors	70 (55, 80)			66 (55–77)		
Survivors	63 (52, 74)			61 (51–71)		
Women, No. (%)	3,861 (36.1)	6.6	1.0	325 (22.3)	22.5	1.0
Men, No. (%)	6,804 (63.7)	8.6	1.34 (1.15–1.56)	1,131 (77.7)	21.1	0.98 (0.73–1.32)
Presumed cardiac, No. (%)	9,776 (91.7)	7.9	1.0			
Noncardiac cause, No. (%)	882 (8.3)	7.6	0.96 (0.74–1.25)			
Location of arrest, No. (%)						
Not public	9,037 (84.6)	6.1	1.0	990 (67.9)	19.1	1.0
Public	1,639 (15.4)	17.4	3.25 (2.79–3.79)	467 (32.1)	28.7	1.71 (1.32–2.20)
Witness status, No. (%)						
Not bystander witness	5,166 (49.4)	2.9	1.0			
Bystander witness	4,236 (40.5)	11.4	4.26 (3.53–5.14)			
EMS witnessed	1,061 (10.1)	18.2	7.38 (5.90–9.25)			
Bystander CPR, No. (%)						
No bystander CPR	5,935 (57.2)	5.1	1.0	677 (47.4)	19.9	1.0
Bystander CPR	3,371 (32.5)	9.7	2.01 (1.71–2.37)	751 (52.6)	24.5	1.30 (1.01–1.68)
EMS witnessed[†]	1,061 (10.2)	18.2	4.15 (3.42–5.04)	— —		
EMS response interval, min, No. (%)						
0–4	2,579 (24.7)	10.4	1.53 (1.31–1.78)	393 (27.2)	28.8	1.65 (1.26–2.15)
>4	7,874 (75.3)	7.0	1.0	1,051 (72.8)	19.7	1.0
EMS response interval, median (IQR)	5.4 (4.0, 7.0)		0.92 (0.89–0.94)	5.2 (4.0, 6.6)		0.89 (0.84–0.94)
Nonsurvivors	5.5 (4.1, 7.0)			5.3 (4.0, 6.8)		
Survivors	5.0 (3.9, 6.4)			4.8 (3.8, 6.0)		
Site, No. (%)						
A	2,939 (27.5)	4.6	1.0	313 (21.5)	14.1	1.0
B	2,152 (20.1)	5.3	1.17 (0.91–1.51)	312 (21.4)	12.5	0.87 (0.55–1.38)
C	1,901 (17.8)	8.6	1.96 (1.55–2.49)	340 (23.3)	22.4	1.76 (1.17–2.65)
D	648 (6.1)	8.8	2.02 (1.46–2.79)	80 (5.5)	26.2	2.18 (1.20–3.93)
E	650 (6.1)	9.8	2.29 (1.68–3.12)	77 (5.3)	23.4	2.46 (1.46–4.16)
F	959 (9.0)	9.9	2.30 (1.75–3.03)	108 (7.4)	28.7	1.87 (1.01–3.46)
G	1,432 (13.4)	14.7	3.62 (2.88–4.54)	229 (15.7)	41.0	4.26 (2.82–6.44)
Initial rhythm, No. (%)						
VF/VT	2,456 (23.9)	21.1	1.0			
PEA	2,169 (21.1)	5.3	0.21 (0.17–0.26)			
Asystole	4,313 (41.9)	1.0	0.04 (0.03–0.05)			
AED no shock[‡]	1,172 (11.4)	3.3	0.13 (0.09–0.18)			
Indeterminate	187 (1.8)	22.5	1.09 (0.76–1.56)			

OHCA, Out-of-hospital cardiac arrest; *VT,* ventricular tachycardia; *VF,* ventricular fibrillation; *IQR,* interquartile ratio; *PEA,* pulseless electrical rhythm; *AED,* automated external defibrillator.

*Among all rhythm arrests, information was missing for sex (n=16), cause (n=23), location (n=5), witness status (n=218), bystander CPR (n=314), EMS time interval (n=223), and initial rhythm (n=384). Among bystander-witnessed VF/VT caused by presumed heart disease, information was missing for sex (n=3), location (n=2), bystander CPR (n=31), and EMS time interval (n=14).

[†]EMS-witnessed arrests receive CPR from EMS and are generally not eligible for bystander CPR.

[‡]AED no shock was assigned when the AED did not shock with the first analysis but a rhythm strip was not available to distinguish between asystole and pulseless electrical rhythm.

collectively by the Utstein data elements ranged from 68% to 78% among all EMS-treated arrests and 20% to 54% among bystander-witnessed ventricular fibrillation or ventricular tachycardia arrest because of presumed cardiac cause.

Figure 3A and B presents the unadjusted and adjusted ORs of site in relation to survival to hospital discharge for the Utstein data elements among all EMS-treated arrests and bystander-witnessed ventricular fibrillation or ventricular tachycardia

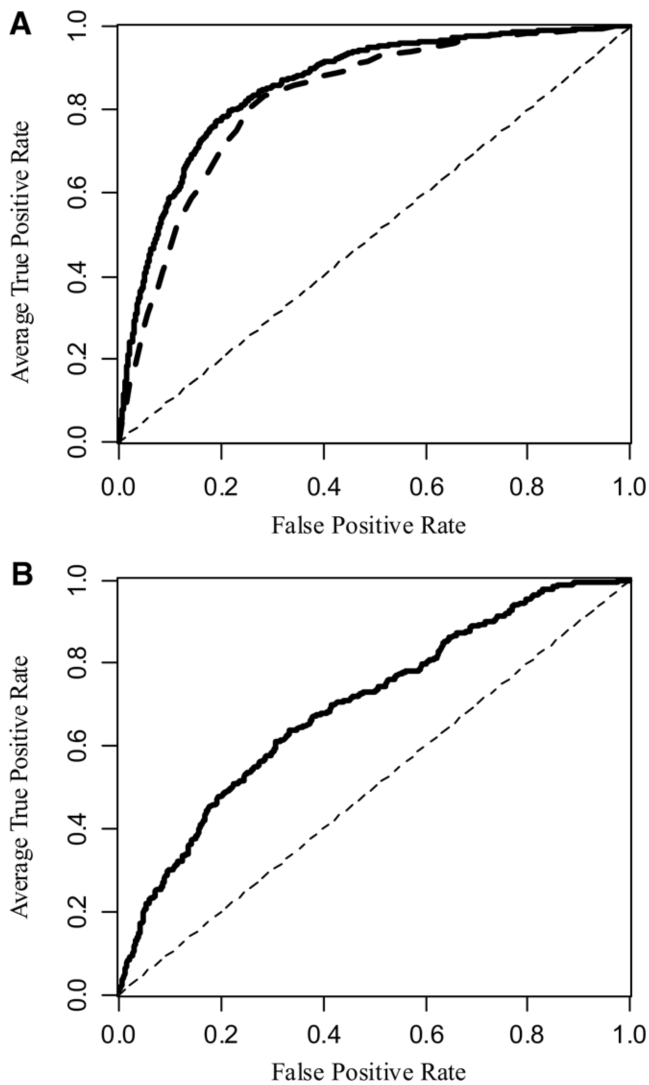

Figure 2. *A,* Receiver operating curve for initial rhythm and for the Utstein elements among all EMS-treated cardiac arrests (n=9,668). *B,* Receiver operating curve for the Utstein elements among bystander-witnessed ventricular fibrillation arrest because of presumed cardiac cause (n=1,412).

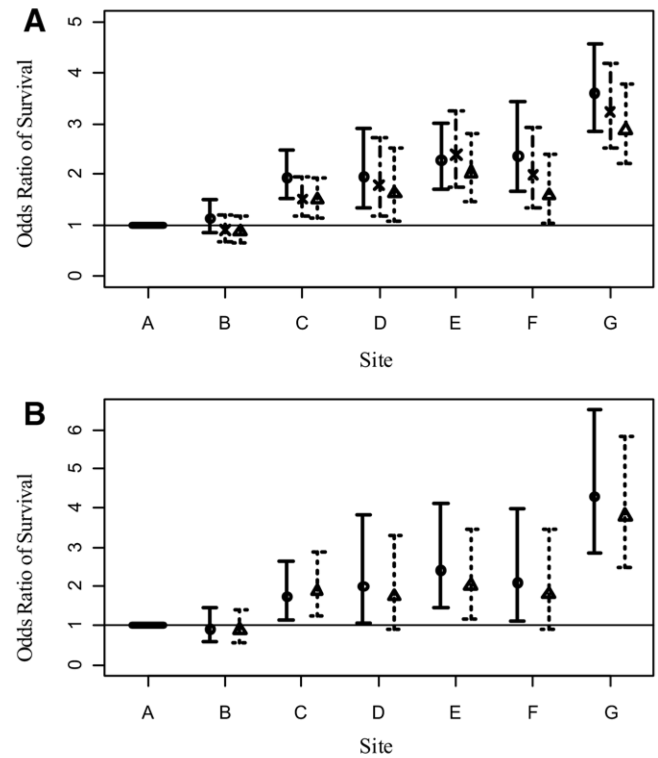

Figure 3. *A,* OR of survival according to site among all EMS-treated arrests unadjusted, adjusted for rhythm alone and adjusted for the Utstein elements (n=9,668). *B,* OR of survival according to site among bystander-witnessed ventricular fibrillation arrest because of presumed cardiac cause unadjusted and adjusted for the Utstein elements (n=1,412).

because of presumed cardiac cause. Adjustment for the Utstein data elements partially attenuated the OR related to site among all EMS-treated arrests and bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause. Quantitatively, the Utstein data elements accounted for an average 43.7% of the between-site survival difference among all EMS-treated arrests and an average 22.3% of the between-site difference among bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause. In a sensitivity analysis that also clustered on the individual EMS agencies within each site, we observed no significant clustering at the agency level (EMS agency variance 0.03 [SD 0.18]). In this sensitivity analysis, the Utstein data elements accounted for an average of 44.2% of the between-site survival difference among all EMS-treated arrests and an average of 22.3% of the between-site difference among bystander-witnessed ventricular fibrillation because of presumed cardiac cause.

LIMITATIONS

This investigation has important limitations. Information was not available about hospital care of these patients. Some of the unexplained outcome variation may be due to differences in hospital-based treatments such as induced hypothermia, which can affect survival.[14-16] Although the current study is a prospective investigation that used uniform data definitions, misclassification of data elements may still have occurred. Moreover, 10% of cases had missing covariate data (3% of the ventricular fibrillation cases). A consequence of this missing data and misclassification might be underestimation of the association between the Utstein data elements and outcome, which would in turn underestimate the extent that the Utstein elements explain survival variability. Efforts were made during data collection and entry to achieve uniform coding and classification. To reduce potential bias because of missing data, we restricted the analysis to 7 of the 11 Resuscitation Outcomes Consortium sites that more consistently reported the Utstein characteristics. This restriction may reduce the generalizability of the results, though the 4 sites excluded from the analysis had a comparable survival rate of 6.8% (range 2.5% to 11.8%) compared with sites included in the analysis of 7.8% (range 4.6% to 14.7%).

Many sites were composed of multiple EMS agencies. Although these multiple agencies within a site often operated with similar training or local protocols, there were also likely some differences among respective EMS agencies within a site. This circumstance may have produced heterogeneity within a site. This heterogeneity could increase or decrease the extent to which the Utstein elements explained between-site variability. In sensitivity analyses, however, inclusion of EMS agency in the models did not appreciably alter the extent to which the Utstein elements accounted for between-site differences. Our multivariable analysis did not evaluate all potential interactions between the Utstein variables so that a model with all possible interactions could explain more of the survival variability. We did assess the interaction between bystander CPR and EMS response interval. We decided to limit interaction assessment to relationships based on scientific plausibility to reduce potential issues caused by overfitting.

The investigation did not have information about functional status of survivors. Functional status among survivors is a more clinically meaningful outcome than simply survival. Most studies indicate that arrest survivors experience satisfactory functional status and life expectancy that approaches that of age- and sex-matched persons who did not experience cardiac arrest.[17,18] Nonetheless, the Utstein data elements may have accounted for more of the prognostic variability if the primary outcome was functional survival status because some evidence indicates that the Utstein elements are associated specifically with functional status.[19] Although the study is a population-based North American experience, the results may not generalize in some instances. For example, many European systems use physicians for the care of out-of-hospital cardiac arrest.

DISCUSSION

In this large, multisite study of EMS-treated out-of-hospital cardiac arrest, the Utstein data elements predicted survival but accounted for only a portion of the outcome variability among all EMS-treated arrests and the subset with bystander-witnessed ventricular fibrillation arrests or ventricular tachycardia because of presumed cardiac cause. Although Utstein data elements predict survival overall and within sites, they account for only a modest portion of survival differences between sites. Taken together, the findings indicate that the current core Utstein data elements are a worthwhile foundation to guide care. However, efforts to improve resuscitation will benefit from additional work to better understand and identify other survival determinants.

The distribution of Utstein elements in this Resuscitation Outcomes Consortium cohort is comparable to that of previous population-based research on out-of-hospital cardiac arrest.[20] Also, survival among all EMS-treated arrests and bystander-witnessed ventricular fibrillation because of presumed cardiac cause observed in this investigation was comparable to that of previous summary reports of cardiac arrest outcome.[2,3] Furthermore, the relationship between these Utstein elements and survival was consistent with that of previous investigations.[21-23] The combination of the population-based design, the large sample size, the comparable distribution of patient, circumstance, care, and outcome characteristics, and the consistent relationship between the Utstein data elements and survival suggests that the findings from Resuscitation Outcomes Consortium investigations may be broadly generalizable to other communities.

Collectively, the Utstein data elements predicted a portion of survival variability, as evidenced by the receiver operating curves, 72% among all EMS-treated arrests and 40% among bystander-witnessed ventricular fibrillation because of presumed cardiac cause. Prediction was better in the all arrest analysis, largely because of the strong survival associations related to initial rhythm, in which survival varied 20-fold between asystole and ventricular fibrillation. The Utstein template defines bystander-witnessed ventricular fibrillation or ventricular tachycardia because of presumed cardiac cause as a standard subset for evaluation and comparison. This clinical group is designated in part because survival in this set of patients may reflect each link in the chain of survival—early activation, early CPR, early defibrillation, and appropriate advanced care—providing the best chance for survival. Indeed, although this group constituted only about 15% of the entire cohort, they accounted for nearly 40% of all survivors, with a survival rate of 22%. However, according to receiver operating characteristic curves, the Utstein data elements explained only about 40% of survival variability among this group for whom each link is relevant. A previous investigation of a single community observed a comparable finding; traditional core predictors accounted for only a modest portion of overall survival variability among ventricular fibrillation arrests.[24]

An assessment of between-site variability produced a similar result, with Utstein data elements accounting for a relatively modest portion of the differences in probability of survival between sites, 43.7% among all EMS-treated arrests and 22.3% among bystander-witnessed ventricular fibrillation. Previous reports indicate that survival from ventricular fibrillation, for example, varies some 30- to 40-fold across communities.[2,3] The current investigation suggests that these substantial outcome differences may not be completely explained by differences in the Utstein elements.

What are the implications of these results? The Utstein data elements are predictive of survival and consequently are a useful basis to assess cardiac arrest care and identify areas to improve outcome. However, the results also indicate that our understanding and measurement of why some patients survive and others do not is far from complete. For example, increasing evidence indicates that CPR is not a simple categorical yes/no treatment, but rather the timing and composition of CPR, especially as it relates to defibrillation, may influence survival.[25-28] One explanation is that there were substantial interindividual or intersite differences in CPR that accounted for outcome variability. If this is the circumstance and we can better determine optimal CPR, then approaches that readily standardize and improve the quality of CPR across rescuers may improve outcomes across all individuals and communities and in turn reduce the unexplained variability.[29]

Alternatively, novel predictors may also help explain survival variability and in turn potentially guide care. For example, previous investigations indicate that a patient's chronic health conditions strongly influence the likelihood of resuscitation from ventricular fibrillation arrest.[24,30] These chronic conditions likely contribute to the underlying physiology of the arrest, and differences in the myocardial substrate may account for survival differences between individuals presenting with ventricular fibrillation. Moreover, these differences in substrate may suggest distinct treatments based on physiologic status.[30,31] Yet information about chronic health conditions or the underlying physiologic substrate is not routinely measured or incorporated into care. The physiologic status of the myocardium may be reflected by the ventricular fibrillation waveform, which can be assessed with a variety of quantitative measures.[32] These waveform measures likely explain at least some of the interindividual survival differences. Potentially, integration of the ventricular fibrillation waveform information can help direct or even change specific aspects of care, depending on the individual patient, and in turn improve outcome and possibly reduce variability in survival.

Other less discrete or quantifiable factors may influence outcome and explain interindividual or intersite survival differences. Case volume and physician experience have been identified as important prognostic characteristics in some procedural specialties; the training and experience of the EMS provider and the receiving hospital may have an analogous role in determining outcome.[33] Some evidence suggests that the design of the EMS system—single-tier response versus a 2-tier response—may influence survival.[34] Other features of the EMS system—for example, the number of EMS providers who respond to a cardiac arrest—may also influence outcome. Quality assurance, medical oversight, and systematic process implementation also have a role in improving care.[35,36] Whether these factors may affect survival through mechanisms captured by the Utstein elements or by other measures is uncertain.

In this large, multisite investigation, the Utstein data elements predicted survival after out-of-hospital cardiac arrest. However, these elements explained a relatively modest portion of survival variability overall and between Resuscitation Outcomes Consortium sites. The results underscore the need for ongoing efforts to better understand and measure characteristics that influence survival after out-of-hospital cardiac arrest.[37] Although a formidable challenge, such an understanding may provide the basis to improve care and ultimately reduce the public health burden of out-of-hospital cardiac arrest.

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