Prehospital traumatic cardiac arrest: Management and outcomes from the resuscitation outcomes consortium epistry-trauma and PROPHET registries

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BACKGROUND: Traumatic arrests have historically had poor survival rates. Identifying salvageable patients and ideal management is challenging. We aimed to (1) describe the management and outcomes of prehospital traumatic arrests; (2) determine regional variation in survival; and (3) identify Advanced Life Support (ALS) procedures associated with survival.

METHODS: This was a secondary analysis of cases from the Resuscitation Outcomes Consortium Epistry-Trauma and Prospective Observational Prehospital and Hospital Registry for Trauma (PROPHET) registries. Patients were included if they had a blunt or penetrating injury and received cardiopulmonary resuscitation. Logistic regression analyses were used to determine the association between ALS procedures and survival.

RESULTS: We included 2,300 patients who were predominately young (Epistry mean [SD], 39 [20]years; PROPHET mean [SD], 40[19] years), males (79%), injured by blunt trauma (Epistry, 68%; PROPHET, 67%), and treated by ALS paramedics (Epistry, 93%; PROPHET, 98%). A total of 145 patients (6.3%) survived to hospital discharge. More patients with blunt (Epistry, 8.3%; PROPHET, 6.5%) vs. penetrating injuries (Epistry, 4.6%; PROPHET, 2.7%) survived. Most survivors (81%) had vitals on emergency medical services arrival. Rates of survival varied significantly between the 12 study sites ($p = 0.048$) in the Epistry but not PROPHET ($p = 0.14$) registries.Patients in the PROPHET registry who received a supraglottic airway insertion or intubation experienced decreased odds of survival (adjusted OR, 0.27; 95% confidence interval, 0.08–0.93; and 0.37; 95% confidence interval, 0.17–0.78, respectively) compared to those receiving bag-mask ventilation. No other procedures were associated with survival.

CONCLUSIONS: Survival from traumatic arrest may be higher than expected, particularly in blunt trauma and patients with vitals on emergency medical services arrival. Although limited by confounding and statistical power, no ALS procedures were associated with increased odds of survival. (*J Trauma Acute Care Surg.* 2016;81: 285–293. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic study, level IV.

KEY WORDS: Cardiac arrest; prehospital; emergency medical services; resuscitation; intubation.

Traumatic cardiac arrest occurs when a severely injured patient ceases to produce spontaneous cardiac output. Survival rates from traumatic arrest have been poor, with approximately 2% of patients surviving to hospital discharge.[1] However, more contemporary studies from diverse settings and locations including military experience,[2] Australia,[3] England,[4] the United States,[5] Spain,[6] and a recent systematic review[7] report survival rates between 5% and 8%.

Although there has long been the recognition that certain patients with traumatic arrest are "salvageable" if the cause for their cardiac arrest is rapidly treated (such as those with airway obstruction, tension pneumothorax, cardiac tamponade, or hypovolemia), it is also recognized that many prehospital traumatic arrest patients are transferred to hospitals under a "lights and sirens" approach and undergo futile and costly resuscitation efforts, including resuscitative thoracotomies.[8,9] Guidelines have been developed to identify patients from whom resuscitation efforts should be withheld or terminated in the field[1] and emergency department settings.[8–10] Concurrently, narrative reviews proposing treatment algorithms for traumatic arrest patients have been published that emphasize the early treatment of reversible causes of arrest[11,12] and selective use of resuscitative thoracotomy.[8,9]

The issue of identifying potentially salvageable traumatic arrest patients in the prehospital setting is complicated by the competing issues of regional variation in the prehospital management and transport practices of these patients. Approximately 50% of traumatic arrests occur in the prehospital setting[13,14] and

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the optimal treatment strategy for these patients is not clear. Recent studies demonstrate wide regional variation in the use of prehospital advanced airways,[13,15] rates of transport following traumatic arrest,[13] and overall rates of survival following severe injury.[13] Although there is ongoing debate regarding the benefit of prehospital advanced life support interventions in trauma, one recent study did find that such interventions were associated with decreased mortality in patients with signs of life at the scene of injury.[16]

Given the variation in both reported survival rates and clinical management of traumatic arrest patients, we had three objectives: first, to describe the contemporary management and outcomes of prehospital traumatic arrest in a large North American trauma patient arrest cohort; second, to determine if there was regional variation in the rate of survival following traumatic arrest; and third, to determine if any prehospital Advanced Life Support (ALS) procedure was associated with the likelihood of survival to hospital discharge.

METHODS

Study Design

This study was a secondary analysis using data from the Resuscitation Outcomes Consortium (ROC). Two different databases were used to capture trauma patients, the ROC Epistry-Trauma and the Prospective Observational Prehospital and Hospital Registry for Trauma (PROPHET).

Study Setting

The ROC trauma registries have been described in detail previously.[15,17,18] These registries include severely injured patients cared for within nine emergency medical services (EMS) regions in the United States (Alabama, Dallas-Ft. Worth, Iowa, Memphis, Milwaukee, Pittsburgh, Portland, San Diego, and Seattle-King County) and three in Canada (Ottawa, Toronto, and British Columbia). Overall, the regions are highly variable in location, size, geography, socioeconomic status, and EMS system configuration.[17,19] All patients with the inclusion criteria described below were included in the registry. Each site obtained REB/institutional review board approval for the ROC data registries and was granted a waiver of consent owing to minimal risk.

Selection of Participants

Subjects were selected from the ROC Epistry-Trauma registry (December 1, 2005 to October 26, 2007) and the PROPHET registry (January 1, 2010 to June 30, 2011). These intervals reflect the start and finish dates for each registry. The inclusion and exclusion criteria differed slightly between the two registries. Both registries enrolled patients who had out-of-hospital injury and were evaluated and treated by EMS personnel, in addition to meeting registry-specific criteria. For Epistry-Trauma, patients had to meet one or more of the following: systolic blood pressure, ≤90; respiratory rate, <10 or >29; Glasgow Coma Scale (GCS) score, ≤12; intubated in the field; or died in the field. For PROPHET, patients had to meet one or more of the following: systolic blood pressure, ≤90 or GCS score, ≤8 before sedation or placement of an advanced airway with RSI. Additionally, PROPHET patients had to be transported to a Level I/II trauma center or die in the field or en route with the intention of transporting to a Level I/II trauma center. Lastly, patients were excluded from PROPHET if there was declaration of nonsurvivability without treatment by EMS personnel or if they were a case of hanging, drowning, primary burn, or blunt/penetrating injury with burn injury >20% of total body surface area.

There was no direct data capture of whether or not a patient had a traumatic arrest in either registry. Thus, we defined traumatic arrest as having occurred if a patient was known to have received prehospital cardiopulmonary resuscitation (CPR) by EMS providers. This includes patients who died on the scene and were not transported to the hospital. Patients were excluded from the study if they had unknown survival to discharge status or did not have a blunt or penetrating injury.

Variables

We noted basic demographic features, including age, sex, injury type (blunt vs. penetrating), injury mechanism (fall, motor vehicle collision, motorcycle collision, etc.), location of injury (street/highway, public building, etc.), ROC registry (Epistry-Trauma or PROPHET), and blinded study site.

The following prehospital interventions were considered as predictive variables in the regression model: ALS-trained paramedic crew first on scene (vs. BLS crew first on scene), Supraglottic airway insertion, endotracheal intubation, needle thoracostomy, intravenous fluid administration, intraosseous fluid administration, and external hemorrhage control. These interventions were all dichotomous or categorical variables.

Outcomes

The primary outcome was survival to hospital discharge. The secondary outcome, neurologic status at discharge (measured within 72 hours of hospital discharge by Glasgow Outcome Scale[20] for patients with documented GCS score of <15 and assumed good for patients with GCS score of 15), was evaluated only in surviving patients from the PROPHET registry. Neurologic status at discharge was not documented in Epistry-Trauma. This outcome was determined by nonblinded data abstractors based on review of clinical documentation.

Statistical Analysis

Data were collected from the prehospital and in-hospital setting using dispatch, EMS, and hospital records based on Utstein data definitions.[21] Standardized data collection forms were collated at each of the study sites, and de-identified information was submitted via a secure Web-based server to a central coordinating center.[17] Quality assurance mechanisms included EMS provider training, data range and consistency checks, site-specific mechanisms, and annual site visits.[17]

We used descriptive statistics (mean and standard deviation [SD]) for continuous variables, frequencies, and percentages for categorical variables) to assess the traumatic arrest cohort in demographics, types and mechanisms of injury, location of injury, prehospital interventions, and outcomes. The X^2 and Fisher exact tests were used to assess for associations between categorical exposure variables and survival outcomes.

The primary outcome was described for the following: (1) the entire cohort, (2) by type of injury, (3) by study site, and (4) by prehospital procedures received. Results are presented stratified by registry because of the differing enrollment periods and inclusion criteria for the Epistry and PROPHET registries.

We used multiple logistic regression to estimate the associations (adjusted odds ratios with 95% confidence intervals [CI]) between prehospital interventions and survival to hospital discharge. The *independent variables* in this model were the prehospital interventions, and the *dependent variable* was the primary outcome (survival to hospital discharge). *Covariates* included in the model were patients' age (as a continuous variable) and other possible confounding variables.

We identified a priori that the presence of vitals on EMS arrival, type of injury, and ROC study site could be *confounding variables*. "Vitals on EMS arrival" was defined as the known presence of any vital sign (heart rate, blood pressure, or respiratory rate) upon initial assessment by EMS providers. This was based on the first set of vitals recorded by EMS regardless of the time at which they were taken. Vital sign times were only recorded in PROPHET and for those patients with available times (57%), the time from arrival at patient side to taking the first set of vital signs has a median of 2 minutes (25th and 75th percentiles: 0 and 7 minutes). Initial vital signs are important predictors of survival following traumatic arrest and were used as a surrogate marker of injury severity.[1,5] Other markers of injury severity such as presenting cardiac rhythm or signs of life at the scene (such as reactive pupils) were not collected in either data registry.

Type of injury was identified as a confounding variable because it has previously been shown to be associated with outcome from traumatic arrest,[1,8,22] and we felt this could influence whether EMS providers perform critical procedures or transport patients to the hospital. Resuscitation Outcomes Consortium ROC study site was adjusted as a way to control for unmeasured confounders at the research site level.

While we fit separate models for each registry, the variables included in the models were the same between registries with one exception. The prehospital intervention of needle thoracostomy was only included in the PROPHET model, as these data were not collected in Epistry.

TABLE 1. Baseline Characteristics of Traumatic Arrest Cohort by Registry*†

	Epistry			PROPHET		
	Survivors (n = 92)	Nonsurvivors (n = 1,200)	*p* Value	Survivors (n = 53)	Nonsurvivors (n = 955)	*p* Value
Sex: male	73 (80%)	939 (78%)	0.79	42 (79%)	755 (79%)	1
Age, years			0.57			0.20
<5	3 (3.4%)	30 (2.7%)		2 (3.8%)	21 (2.3%)	
5–9	0 (0%)	12 (1.1%)		0 (0%)	5 (0.54%)	
10–19	12 (13%)	109 (9.6%)		7 (13%)	72 (7.8%)	
20–39	40 (45%)	469 (41%)		17 (33%)	388 (42%)	
40–59	21 (24%)	322 (28%)		21 (40%)	276 (30%)	
60–79	12 (13%)	143 (13%)		5 (9.6%)	123 (13%)	
≥80	1 (1.1%)	46 (4.1%)		0 (0%)	37 (4%)	
Mechanism of injury‡						
Fall	21 (23%)	158 (13%)	0.015	15 (28%)	134 (14%)	0.008
MVC—occupant	30 (33%)	326 (27%)	0.32	14 (26%)	226 (24%)	0.77
MVC—motorcyclist	3 (3.3%)	62 (5.2%)	0.62	2 (3.8%)	59 (6.2%)	0.77
MVC—pedestrian	4 (4.3%)	138 (12%)	0.052	2 (3.8%)	118 (12%)	0.097
Gunshot wound	8 (8.7%)	303 (25%)	0.001	4 (7.5%)	259 (27%)	0.003
Stab	11 (12%)	82 (6.8%)	0.11	5 (9.4%)	64 (6.7%)	0.402
Other	14 (15%)	119 (9.9%)	0.15	11 (21%)	126 (13%)	0.175
Injury type: blunt	73 (79%)	802 (67%)	0.018	44 (83%)	628 (66%)	0.014
Location of injury			0.17			0.021
Street/highway	44 (48%)	670 (56%)		28 (53%)	537 (56%)	
Public building	2 (2.2%)	33 (2.8%)		1 (1.9%)	12 (1.3%)	
Place of recreation	1 (1.1%)	24 (2%)		3 (5.7%)	15 (1.6%)	
Industrial place	1 (1.1%)	34 (2.8%)		0 (0%)	23 (2.4%)	
Home residence	28 (30%)	289 (24%)		10 (19%)	269 (28%)	
Other public	11 (12%)	130 (11%)		8 (15%)	85 (8.9%)	
Other private	5 (5.4%)	20 (1.7%)		3 (5.7%)	14 (1.5%)	
Vital signs present on EMS arrival	74 (80%)	245 (20%)	<0.001	43 (81%)	348 (36%)	<0.001

*Summaries are n (%), where percent is of nonmissing. Note that *p* values are presented for descriptive purposes only and no correction for multiple testing has been made.
†Abbreviations used: MVC, motor vehicle collision; and EMS, emergency medical service.
‡Patients may have more than one mechanism of injury.

Notably, all of the variables in our model were specified a priori to examining the data. However, we did originally consider the same model but with an interaction term between type of injury and each prehospital intervention to assess for differing associations between interventions and survival for those with penetrating versus blunt injuries. Here, we present the model without these interactions included. The variables included in the model, as well as the rates of missing data for each variable, are summarized in Appendix 1 (see Appendix, Supplemental Digital Content 1, http://links.lww.com/TA/A757).

To retain power and reduce bias, we used multiple imputation[23] to handle the missing data. Twenty multiply imputed data sets were generated and analyzed separately using standard logistic regression. Then results from each of these models were combined using the results of Rubin (1987)[23] to properly account for the uncertainty inherent in imputing the missing data. All baseline variables (i.e., those listed in Table 1), variables included in the logistic regression model (i.e., those listed in Appendix 1, http://links.lww.com/TA/A757), an indicator of whether the patient was an adult and the outcome of survival were used in the imputation procedure to predict missing covariate values. We assessed model fit using the Hosmer-Lemeshow goodness-of-fit test. Likelihood ratio tests were performed for each of the prehospital interventions to test the hypothesis that the odds of survival differed between those receiving and not receiving the intervention.[24]

Additionally, a likelihood ratio test was used to test the hypothesis that the odds of survival following traumatic arrest vary with ROC study site. We compared the primary model to the reduced model that does not include adjustment for ROC site. An alpha level of 5% was used to determine statistical significance. All analyses were conducted using R version 3.0.2 and the R package mice.[25]

RESULTS

There were 13,291 patients enrolled in Epistry-Trauma and 6,258 patients enrolled in PROPHET during the study period. Of these patients, 1,412 (10%) and 1,012 (16%) patients, respectively, received prehospital CPR. Of the patients receiving CPR, 85 patients (6.0%) in Epistry-Trauma did not have a blunt or penetrating injury and were excluded. Of the remaining patients who had a blunt or penetrating trauma and received CPR, 35 from Epistry-Trauma and four from PROPHET were excluded because their discharge status was unknown (Fig. 1).

Baseline characteristics of the traumatic arrest cohort, stratified by registry and survival status, are presented in Table 1. The study population included 2,300 traumatic arrest patients who were predominately young (Epistry: mean [SD], 39 [20] years; PROPHET: mean [SD], 40 [19]years), male (79%), and injured by blunt trauma (Epistry, 68%; PROPHET, 67%). The three most common injury mechanisms were motor vehicle collisions (Epistry, 28%; PROPHET, 24%), gunshot wounds (Epistry, 24%; PROPHET, 26%), and falls (Epistry, 14%; PROPHET, 15%). Most traumatic arrests occurred on streets and highways (Epistry, 55%; PROPHET, 56%), followed by the patient's home (Epistry, 25%; PROPHET, 28%), and other public property (store, bar, restaurant, etc.) (Epistry, 11%; PROPHET, 9%).

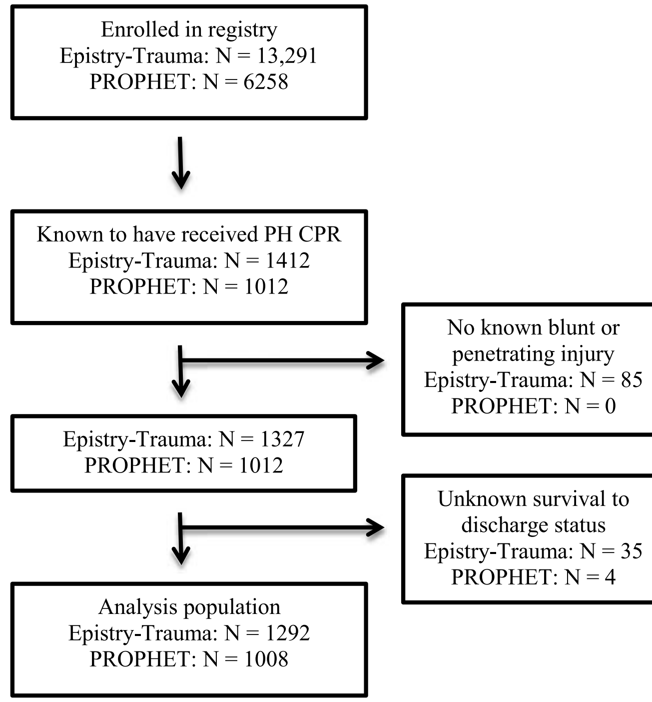

Figure 1. Study population.

Outcomes following traumatic arrest are summarized in Tables 1 and 2.

Overall, 145 patients (6.3%) survived to hospital discharge following traumatic arrest. Survival rates were similar between Epistry and PROPHET patients (7.1% vs. 5.3%; $p = 0.082$). More patients (39%) in PROPHET than Epistry (25%) had vital signs initially present on EMS arrival ($p < 0.001$). Eighty-one percent of the surviving patients had vital signs on EMS arrival. Approximately 70% of patients were transported and admitted to an emergency department (ED) with a minority of patients having a pulse present at ED admission. Among patients with a pulse present at ED admission, rates of survival were 26% (Epistry) and 22% (PROPHET). In comparison, only 7.0% (Epistry) and 1.7% (PROPHET) who were receiving CPR at ED admission survived to hospital discharge.

When stratified by the presence or absence of vital signs upon EMS arrival, rates of survival were 23% (95% CI, 19–28%) and 1.8% (95% CI: 1.1–3.0%), respectively, in Epistry and 11% (95% CI, 8.2–15%) and 1.6% (95% CI, 0.83–3.1%), respectively, in PROPHET. Traumatic arrest patients who had a fall were the most likely to survive to discharge (11%), whereas those with one or more gunshot wounds were the least likely (2.1%) (Table 1). Overall, patients with blunt traumatic arrest had higher rates of survival (Epistry, 8.3%; PROPHET, 6.5%) than those with traumatic arrest from penetrating mechanisms (Epistry, 4.6%; PROPHET, 2.7%). Although the absolute number of survivors with a documented neurologic outcome within 72 hours of hospital discharge was small, there were survivors in both the blunt and penetrating traumatic arrest cohorts who made a good neurologic recovery (41% for blunt and 89% for penetrating; Table 2).

TABLE 2. Outcomes in Traumatic Arrest Patients by Injury Type and Registry*

	Epistry			PROPHET		
	Blunt (n = 875)	Penetrating (n = 417)	*p* Value	Blunt (n = 672)	Penetrating (n = 336)	*p* Value
Prehospital status			0.20			<0.001
Prehospital declaration of death without ED admission	237 (27%)	128 (31%)		232 (35%)	79 (24%)	
Transported and admitted to ED	638 (73%)	289 (69%)		440 (65%)	257 (76%)	
Patient status at ED arrival of those admitted			0.054			<0.001
Pulse present†	81 (21%)	25 (14%)		147 (34%)	52 (21%)	
Ongoing resuscitation†	313 (79%)	160 (86%)		285 (66%)	198 (79%)	
Unknown‡	20 (3.1%)	12 (4.2%)		8 (1.8%)	7 (2.7%)	
Not collected‡	224 (35%)	92 (32%)		0 (0%)	0 (0%)	
Survival to hospital discharge	73 (8.3%)	19 (4.6%)	0.018	44 (6.5%)	9 (2.7%)	0.014
Neurologic status of survivors§						0.11
Vegetative state				3 (7.7%)	0 (0%)	
Severely disabled				14 (36%)	1 (11%)	
Moderately disabled				6 (15%)	0 (0%)	
Good recovery				16 (41%)	8 (89%)	

* Note that *p* values are presented for descriptive purposes only and no correction for multiple testing has been made.
†Summaries are n (%), where percent is of those admitted to the ED with known status of pulse present or ongoing resuscitation.
‡Summaries are n (%), where percent is of those admitted to the ED. Not collected refers to the period at the beginning of Epistry during which this information was not collected.
§Summaries are n (%), where percent is of survivors with nonmissing status. This was only measured in PROPHET. Of the 53 PROPHET patients who survived, 5 (8%) blunt injury patients were missing this outcome.

Across ROC sites, overall survival following traumatic arrest ranged from 2.9% (95% CI, 0.95–7.8%) to 14% (95% CI, 8.2–24%) (Fig. 2). A likelihood ratio test provided evidence that the odds of survival following traumatic arrest differed among ROC study sites in the Epistry ($p = 0.048$) but not in the PROPHET registry ($p = 0.14$).

The prevalence of prehospital procedures and their association with survival following traumatic arrest is presented in Tables 3 and 4. Overall, 93% of patients in Epistry and 98% of patients in PROPHET were treated by ALS-trained paramedics. The ALS-trained crews were first on scene in 43% of Epistry cases and 53% of PROPHET cases. The median scene time was 17 minutes in both registries (Epistry 25th and 75th percentiles, 12 and 24; PROPHET 25th and 75th percentiles, 11 and 24 minutes). The median transport time was 8 minutes for Epistry (25th and 75th percentiles, 5 and 13 minutes) and 10 minutes for PROPHET (25th and 75th percentiles, 6 and 15 minutes). Most traumatic arrests received either endotracheal intubation (Epistry, 61%; PROPHET, 51%) or bag-mask ventilation (Epistry, 32%; PROPHET, 31%), as well as intravenous fluid resuscitation (Epistry, 57%; PROPHET, 48%). The remainder of the procedures was performed infrequently. The PROPHET patients who received a supraglottic airway insertion or intubation experienced decreased odds of survival (adjusted ORs, 0.27; 95% CI, 0.08–0.93; and 0.37; 95% CI, 0.17–0.78, respectively) compared to those receiving bag-mask ventilation. No other procedures were associated with either increased or decreased odds of survival following traumatic arrest in either registry (Table 4).

There was a lack of fit identified in the Epistry model ($p = 0.03$) but not the PROPHET model ($p = 0.10$). As a sensitivity analysis, both models were refit with age modeled as a

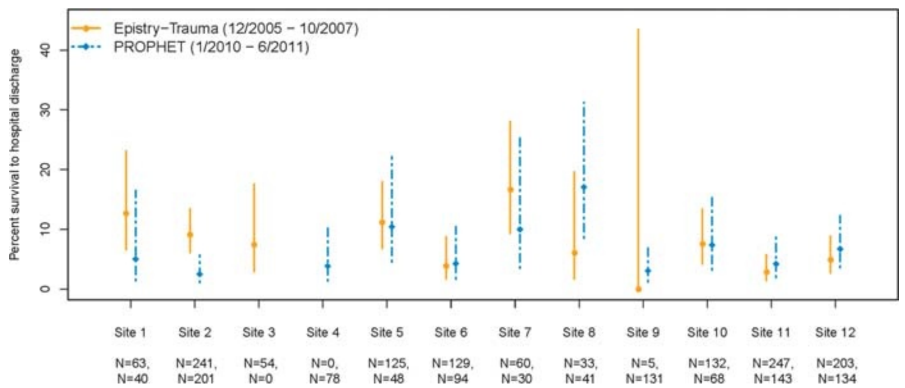

Figure 2. The percentage (with 95% CIs) of cardiac arrest patients surviving to hospital discharge by site and data registry. Enrollment numbers for Epistry-Trauma (top number) and PROPHET (bottom number) are given for each site.

TABLE 3. Prehospital Procedures and Outcomes in Traumatic Arrest Patients by Registry*

	Epistry			PROPHET		
	Patients Receiving	Survival to Hospital Discharge		Patients Receiving	Survival to Hospital Discharge	
Intervention	n (%)†	n (%)	*p* Value	n (%)†	n (%)	*p* Value
EMS training of first rig: ALS			0.085			0.95
Yes	546 (43%)	45 (8.2%)		526 (53%)	27 (5.1%)	
No	712 (57%)	40 (5.6%)		461 (47%)	25 (5.4%)	
Airway intervention			0.32			0.071
Bag-mask ventilation only	401 (32%)	24 (6%)		314 (31%)	22 (7%)	
Supraglottic airway‡	92 (7.3%)	2 (2.2%)		181 (18%)	4 (2.2%)	
Endotracheal intubation	769 (61%)	46 (6%)		513 (51%)	27 (5.3%)	
Needle thoracostomy§						0.76
Yes				138 (14%)	6 (4.3%)	
No				870 (86%)	47 (5.4%)	
Hemorrhage control			0.62			0.46
Yes	173 (15%)	12 (6.9%)		163 (16%)	11 (6.7%)	
No	994 (85%)	56 (5.6%)		845 (84%)	42 (5%)	
Intravenous fluid administration			0.004			0.033
Yes	735 (57%)	66 (9%)		471 (48%)	32 (6.8%)	
No	557 (43%)	26 (4.7%)		504 (52%)	18 (3.6%)	
Intraosseous fluid administration			0.19			0.23
Yes	75 (5.8%)	2 (2.7%)		138 (14%)	4 (2.9%)	
No	1217 (94%)	90 (7.4%)		847 (86%)	49 (5.8%)	

*Note that *p* values are presented for descriptive purposes only and no correction for multiple testing has been made.
†Percent is of nonmissing.
‡With no endotracheal intubation.
§This was only collected for PROPHET patients.

linear spline with a knot at 45 years (compared to linearly as in the original model). The adjusted odds ratios and CIs from these models were very similar to those shown in Table 4.

DISCUSSION

In this large, multicenter, prospective study involving two large trauma registries, we found a contemporary rate of survival from traumatic arrest of approximately 6% (Epistry, 7.1%; PROPHET, 5.3%). This is very similar to the 7.2% rate of survival reported in a recent systematic review that included more than 5,000 children and adults with traumatic arrest,[7] and higher than the 2% rate of survival reported in a recent position statement on withholding and terminating resuscitation for prehospital traumatic arrest.[1]

There are several explanations for the higher-than-expected rate of survival in the traumatic arrests in our study. The first relates to our definition of cardiac arrest being based on the

TABLE 4. Multivariable Logistic Regression Models of Survival to Hospital Discharge*

	Epistry		PROPHET	
Intervention	Adjusted OR (95% CI)†	*p* Value	Adjusted OR (95% CI)†	*p* Value
EMS training of first rig: ALS	1.09 (0.54–2.22)	0.81	0.99 (0.44–2.21)	0.98
Airway intervention		0.25		0.015
Bag-mask ventilation only	Reference		Reference	
Supraglottic airway‡	0.35 (0.08–1.55)		0.27 (0.08– 0.93)	
Endotracheal intubation	0.70 (0.38–1.31)		0.37 (0.17– 0.78)	
Needle thoracostomy§			0.68 (0.26–1.79)	0.42
Hemorrhage control	0.76 (0.37–1.59)	0.47	1.10 (0.50–2.44)	0.82
Intravenous fluid administration	1.40 (0.78–2.49)	0.25	1.41 (0.66–3.01)	0.37
Intraosseous fluid administration	0.32 (0.07–1.52)	0.11	0.44 (0.14–1.37)	0.13

*Abbreviations used: OR, odds ratio (OR).
†Adjustment includes listed interventions as well as ROC study site, age, presence of any vital signs at EMS arrival, and type of injury. Details are provided in Appendix 1.
‡With no endotracheal intubation.
§This was only collected for PROPHET patients.

performance of prehospital CPR by EMS providers. Patients who were pulseless on EMS arrival or who lost a pulse in the presence of EMS would have received CPR and a tentative diagnosis of cardiac arrest. As noted previously, we acknowledge that that some of these patients could have simply been profoundly hypotensive owing to very low cardiac output state but not truly arrested.[26] Although our definition of traumatic arrest is consistent with other studies on the topic,[27–29] we acknowledge that using more specific criteria (such as absence of all signs of life,[29,30] or specific cardiac arrest rhythm), had they been available, may have led us to observe a slightly lower survival rate. However, our data are consistent with recent data from the American College of Surgeons Trauma Quality Improvement Program (ACS TQIP), indicating a 10% rate of survival for patients with a prehospital traumatic arrest, when defined as "prehospital cardiac arrest with resuscitative effort by healthcare provider".[29]

Most (Epistry, 80%; PROPHET, 81%) of surviving traumatic arrest patients had their arrest witnessed by paramedics as indicated by at least one vital sign (heart rate, blood pressure, or respiratory rate) being present on EMS arrival. The EMS-witnessed loss of vital signs is a well-established indicator of prognosis following the onset of traumatic arrest.[1,5] The ROC trauma registries did not include data on when exactly patients lost vital signs or when CPR was initiated in the prehospital setting, so the proximity to the hospital when patients lost their vital signs remains unknown. The higher-than-expected rate of survival could then be partially explained by a greater proportion of EMS-witnessed traumatic arrests.

All of the patients in this study were cared for in well-developed regional trauma systems that included advanced prehospital care practices as well as established hospital-based trauma centers. Ninety-five percent of traumatic arrest patients were treated by ALS-trained paramedics, with approximately half of the patients receiving intubation and fluid resuscitation before hospital arrival. Although we did not find that any ALS interventions were associated with increased odds of a traumatic arrest patient surviving to hospital discharge, the higher survival rates than previously reported may have been associated with unmeasured aspects of ALS care, such as decision making around when to attempt procedures versus rapid transfer to a trauma-specific hospital.

An unexpected finding, consistent between registries, was the more favorable survival rate from blunt compared to penetrating traumatic arrest. This contradicts a recent systematic review that reported lower rates of survival following blunt trauma (3.3%).[7] Another case series of 909 trauma patients requiring prehospital CPR found a 7.9% and 3.3% survival rate for penetrating and blunt trauma, respectively.[4] In that same report, some patients were also classified as having had traumatic arrest from asphyxiation (conflagration, drowning, hanging, etc.) or a "medical" event plus trauma and had survival rates of 30% and 11%, respectively.[4] In our study, we excluded patients with cardiac arrest following hanging, drowning, or significant burns, so we believe our patient population is quite comparable to blunt and penetrating trauma populations reported in previous reviews.

In the present study, the performance of either supraglottic airway insertion or endotracheal intubation was significantly associated with decreased odds of surviving to hospital discharge in PROPHET. The negative association between receiving an advanced airway and survival could be explained by "confounding by indication".[32,33] Specifically, patients who are selected to receive bag-mask ventilation rather than either endotracheal intubation or a supraglottic airway may have a more favorable prognosis than those who receive advanced airways in the field. In this potential scenario, the relationship between the treatment being studied (advanced airway) and the outcome (survival) is biased by the uncontrolled confounding effect of injury severity.

A recent meta-analysis of advanced airway management for out-of-hospital cardiac arrest patients (mostly medical arrests) found a similar association between advanced airway placement and survival but similarly cautioned the interpretation in light of the potential for confounding by indication.[33] Previous studies of advanced airway management for the resuscitation of traumatic arrest victims have been small retrospective studies and similarly found no evidence of benefit.[34,35] Only one randomized controlled trial has examined the benefit of prehospital intubation for trauma patients.[36] That study focused on rapid sequence intubation of brain injured patients rather than arrested trauma patients and found improved functional outcomes at 6 months in the intubation group.[36]

This study suggests that outcomes following severe trauma vary regionally, at least among ROC sites participating in the Epistry registry.[13,37–39] Previous work involving ROC study sites has identified regional variation in withholding and/or terminating prehospital resuscitation efforts for traumatic arrest patients,[13] and this could contribute to some of the variation in survival rates. Additionally, there is also considerable variation in the use of ALS procedures such as intubation between sites,[15] which could further contribute to the differences observed. Finally, although we were not able to explore the specific factors in the current study, there are likely hospital-specific resuscitation practices that contribute to the variation in survival following traumatic arrest.

This study has a few limitations that warrant discussion. First, patients were not randomized to receive prehospital interventions. Paramedics selected which patients to provide interventions to based on clinical judgment and existing protocols. As discussed previously, selection bias, in the form of confounding by indication, is a recognized limitation of this study design. The lack of randomization in this study also means there is possibly an imbalance in confounding variables between patient groups either receiving or not receiving an intervention. Although we did attempt to adjust for known confounders using multiple logistic regression, we were not able to include all variables that affect the prognosis after traumatic arrest or that might influence paramedics' decision making around procedure use in this setting. Residual confounding, especially regarding injury severity, is thus possible.

External generalizability is another limitation of our study. Patients were predominately cared for by ALS paramedics in large, well-developed EMS systems. Although these EMS systems include a population of almost 24 million people (nearly 10% of the North American population)[40] and span diverse geographic and socioeconomic spectrums, rates of survival or associations between procedures and outcomes may not be applicable to EMS systems with different structures or capabilities (physician-led services,[11,12] for instance).

Finally, despite our large sample size from these two registries, the precision of our effect estimates for many procedures was low owing to the poor overall rate of survival from traumatic arrest. For some procedures (like hemorrhage control, or intravenous and intraosseous fluid administration), it is probable that we did not have sufficient power to demonstrate a statistically significant association.

These limitations are balanced by strengths of the study that include the largest population of pediatric and adult traumatic arrest patients in the literature, prospective data collection, a range of large, diverse EMS systems, high rates of data completeness, and the reporting of neurologic outcomes for many survivors of traumatic arrest.

In conclusion, we have found that contemporary rates of survival from traumatic arrest may be more favorable than historically reported, especially in the blunt trauma population. Patients with witnessed traumatic arrests, regardless of type of injury, deserve aggressive resuscitation efforts. Our findings that no prehospital procedure is associated with increased odds of surviving traumatic arrest are limited by the potential for confounding by indication and lack of statistical power for some procedures. Future studies on traumatic arrest patients should include detailed baseline prognostic information on patients to minimize confounding, focus on the indications for and outcomes associated with procedures targeting reversible causes of traumatic arrest (e.g., fluid resuscitation and needle decompression), and characterize within-hospital resuscitative care practices associated with survival.

AUTHORSHIP

C.C.E. and A.P. conceived of and designed the study. A.P. performed database management alone and statistical analyses with assistance from E.M. All authors helped refine the study plan, interpret preliminary results, and refine the analysis. C.C.E. drafted the article, and all authors participated substantially in revisions of the manuscript. C.C.E. takes responsibility for the paper as a whole.

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DISCLOSURE

The authors declare no conflicts of interest.

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