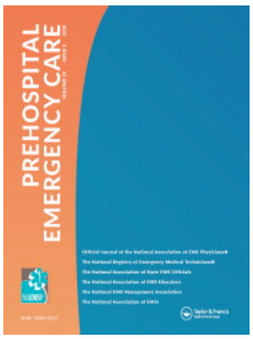

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Epinephrine in Prehospital Traumatic Cardiac Arrest – Life Saving or False Hope?

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ABSTRACT

OBJECTIVES: While epinephrine is widely used for medical cardiac arrests, there is a knowledge gap regarding its utility for traumatic arrests. Traumatic arrests result from hypovolemia, hypoxia, or anatomic impairment of cardiac function such that the inotropic and vasoconstrictive effects of epinephrine may be ineffective or harmful. We hypothesized that epinephrine does not improve survival among patients with traumatic cardiac arrest.

METHODS: This was a multicenter retrospective cohort study of trauma patients sustaining prehospital cardiac arrest who were treated at seven level I and II trauma centers over six years (2011-2017), ascertained via trauma registry data and chart abstraction. The primary outcome was survival to hospital discharge; patients treated with or without epinephrine were compared. Multivariable analyses were performed using Poisson regression. Time to event analyses were conducted using Cox proportional hazard models.

RESULTS: We included 1631 adult and pediatric trauma patients with prehospital cardiac arrest. Prehospital epinephrine was administered to 844 (52%). The median age was 35 years, 335 (21%) were female, 712 (44%) sustained blunt trauma, and 58 (4%) had a shockable initial rhythm. Survival to hospital discharge was significantly lower in the prehospital epinephrine cohort compared to the no epinephrine cohort in univariable analysis [43/844 (5%) vs 125/787 (16%), p<0.001]. Among patients with blunt mechanism, survival was significantly lower in the prehospital epinephrine cohort [12/382 (3%) vs 54/330 (16%), p<0.001]. Among patients with penetrating mechanism, survival was not statistically different [10/276 (4%) with epinephrine vs 22/374 (6%) without, p=0.19]. In multivariable analyses adjusting for age, sex, mechanism, and initial rhythm, epinephrine was associated with lower likelihood of survival in the overall and blunt cohorts; there was no significant difference in the penetrating cohort (overall aRR 0.33, 95% CI 0.23-0.46; blunt aRR 0.20, 95% CI 0.11-0.37; penetrating aRR 0.62, 95% CI 0.30-1.28). Adjusted and unadjusted time to event analyses across each of these

cohorts showed that epinephrine was associated with either statistically inferior or indistinct hazard ratios.

CONCLUSIONS: Epinephrine was not associated with improved survival following traumatic cardiac arrest, and in multiple subanalyses, it was associated with inferior outcomes. These results may inform prehospital traumatic arrest protocols.

Keywords: epinephrine, traumatic arrest, prehospital care

INTRODUCTION

Cardiac arrest from trauma results from severe hemorrhage, hypoxia, or mechanical impairment of cardiac function such as tamponade or tension physiology. This contrasts with medical cardiac arrest, which is most often an electrical abnormality leading to life-threatening dysrhythmias. The American Heart Association Advanced Cardiac Life Support (ACLS) resuscitation algorithms focus on management of medical cardiac arrest, emphasizing defibrillation, closed chest compressions, and use of epinephrine. There is no analogous nationwide guideline specific to traumatic arrest, so these principles may be extrapolated to the care of traumatic cardiac arrest particularly given widespread ACLS training among prehospital, emergency, and trauma clinicians. Traumatic arrest is also much less common than medical arrest, accounting for 1.7-2.4% of out of hospital cardiac arrests (1, 2).

There are limited data regarding the utility of ACLS interventions for traumatic cardiac arrest. Closed chest cardiopulmonary resuscitation may temporize medical cardiac arrest during transport to definitive care, but chest compressions have been shown to be of limited value in the setting of cardiac arrest due to hemorrhagic shock (3, 4). Furthermore, epinephrine's inotropic and vasoconstrictive effects may be less effective for the underfilled, hypoxic, or mechanically impaired heart following trauma.

We hypothesized that epinephrine does not improve survival of patients sustaining traumatic cardiac arrest. The primary objective of this study was to determine if the administration of epinephrine to patients with prehospital traumatic cardiac arrest resulted in improved survival. The secondary objective was to evaluate whether there were select cohorts who derived greater or lesser benefit from epinephrine.

METHODS

Study design and setting

This was a retrospective cohort study, which included data from six United States (U.S.) level I trauma centers and one level II trauma center. Participating institutions included the University of California Davis Medical Center (Sacramento, CA), University of Washington/Harborview Medical Center (Seattle, Washington), University of Miami/Jackson Memorial Hospital (Miami, FL), UCHealth Medical Center of the Rockies (Loveland, CO), Denver Health Hospital Authority (Denver, CO), Emory University/Grady Health System (Atlanta, GA) and Highland Hospital (Oakland, CA). Waiver of informed consent was obtained from the Institutional Review Board of each participating center.

Data collection

Institutional trauma registry data were queried for the six-year period between January 2011 and December 2017 to identify patients admitted with the data field "Prehospital Cardiac Arrest" as defined by the National Trauma Data Standard (NTDS). All patients transported directly from the scene were included, regardless of age, sex, or medical co-morbidities. Interfacility transfers were excluded. Patients were not excluded based on type of transport (such as Advanced Life Support (ALS) or Basic Life Support (BLS)). Patients who were not transported from the scene could not be identified with this dataset. Specific prehospital protocols were not available as institutions may receive patients from multiple agencies, but use of prehospital epinephrine was evaluated across contributing institutions.

Trauma registry, hospital and prehospital medical records were reviewed to determine the mechanism of injury and details surrounding the event. Registry data were collected by trained trauma nurses at each institution and reporting is standardized nationwide in accordance with the NTDS. Additional chart abstraction for relevant variables not available in the registry was performed either by the authors, or by

trained abstractors with subsequent review by the author at each institution. Standardized data definitions were used across sites with a data collection tool. Study data were collected and managed using REDCap electronic data capture tools (5, 6).

Data collected included the use or exclusion of epinephrine in the field and in the emergency department (ED), heart rhythm in the field and ED, Emergency Medical Services (EMS) scene time, injury mechanism, demographics, hospital procedures and discharge outcomes. The primary exposure variable was receipt of prehospital epinephrine vs no prehospital epinephrine. Doses were not reported. Secondarily, data were included regarding the receipt of epinephrine in the ED to create a composite of patients who received epinephrine in either the prehospital or ED setting.

There were 43 patients who met the above inclusion/exclusion criteria but who were suspected to have a primary medical arrest. These patients were identified on evaluation of EMS run reports and chart review, all adjudicated by author D.V.S. These patients had minimal evidence of trauma, very low speed mechanisms, notations of the patient being a driver slumped at the vehicle wheel, and had cardiac catheterization findings of acute coronary findings. These patients were excluded from the analysis.

Outcomes

The primary outcome was survival to hospital discharge. Secondary outcomes included time to death and survival to ED disposition.

Statistical analysis

Descriptive evaluations of patient characteristics and clinical interventions were tabulated across cohorts who received epinephrine in the prehospital setting and those who did not. Pearson's Chi Square tests

were used to assess significance for categorical variables and two-tailed T tests were used for continuous variables. Subanalyses were performed to assess the association between epinephrine use and survival within clinically significant patient strata: injury mechanism, heart rhythm, and age category. Injury mechanisms were listed as reported to the National Trauma Data Bank. These were broken down into categories by mechanism: blunt (motor vehicle crash, motorcycle crash, bicycle vs vehicle, pedestrian vs vehicle, fall from height), penetrating (gunshot wound, stab wound), and blunt and/or penetrating mechanism (inclusive of the blunt and penetrating cohorts, with the addition of assault. Assault was not included in the blunt or penetrating categories due to some patients having mixed blunt and penetrating injuries). These three categories all excluded ground level falls and the "other" category, which variably includes hanging, drowning, and hypothermia at some institutions.

Multivariable analyses were performed. Poisson regression was used to estimate the relative risks of survival, using robust standard errors (a technique to mitigate heteroskedasticity within predictor variables). Time to event analyses were conducted using Cox proportional hazard regression models to estimate unadjusted and adjusted hazard ratios. For construction of the multivariable models, predictor variables were assessed based on pre-arrest factors in Table 1 and included if they caused at least a 10% change in the models based on a forward stepwise model or were deemed relevant based on clinical judgement and literature search. Missingness was assessed in all variables; there was relatively little missing data in the final cohort for key variables (<1% for all of the patient characteristics shown in Table 1), so these were managed with casewise deletion. Initial heart rhythm had missing data for 45 cases (3%) and this was assessed as unknown in the analysis. Statistical analysis was conducted using Stata version 14 (StataCorp LP, College Station, TX).

RESULTS

Information from 1,709 patients was collected. We excluded 35 patients with missing data regarding epinephrine use. We also excluded 43 patients who were considered to have primary cardiac arrests. There were 1,631 patients in the final study cohort. Prehospital epinephrine was administered to 844 patients (52%). Use of prehospital epinephrine varied across the seven receiving institutions (used in 20%, 27%, 49%, 53%, 61%, 72%, and 100% of traumatic arrests, in order of ascending frequency). Patient characteristics and treatment interventions are tabulated in Table 1. The median age for the cohort was 35 years and 335 (21%) were female. The median time from EMS arrival at the scene to ED arrival was 22 minutes; this was slightly longer in the epinephrine cohort (median 20 vs 25 minutes, p<.001). Additional data regarding age distribution, mechanism of injury, heart rhythm, and procedural interventions are shown in the table. Table 2 details survival to hospital discharge based on patient characteristics. Overall survival was 10% (168/1,31). Survival was 5% (32/650) in patients with penetrating mechanism, 9% (66/712) in patients with blunt mechanism, and 8% (109/1,410) in patients with blunt and/or penetrating mechanism (blunt, penetrating, and assault as defined in the methods). Survival was higher in younger patients, those with initial sinus rhythm or a shockable initial rhythm, and with certain mechanisms.

The primary outcome, survival to hospital discharge, is detailed in Figure 1. Survival to hospital discharge was significantly lower in the prehospital epinephrine cohort compared to the no epinephrine cohort [43/844 (5%) vs 125/787 (16%), p<0.001], as well as in the cohort who received epinephrine either prehospital or in the ED. When stratified by mechanism, epinephrine (either prehospital only or prehospital or ED) was associated with poorer survival in the blunt trauma and blunt and/or penetrating mechanism cohorts. Among the penetrating cohort, survival to hospital discharge was not statistically different.

There were no significant differences noted across groups in survival to ED disposition in most groups. The only cohort in which epinephrine showed a statistically significant advantage was the penetrating trauma cohort, with increased survival to ED disposition among patients who received epinephrine either prehospital or the ED.

Survival to hospital discharge by prehospital epinephrine use was assessed in several sub-cohorts to ascertain whether there was greater or lesser benefit to epinephrine in certain patient populations. Among those with an initial shockable rhythm, 4/40 (10%) in the epinephrine cohort survived compared to 7/18 (39%) in the no epinephrine cohort who survived (p=0.009). Among patients age ≥65, 7/102 (7%) in the epinephrine cohort survived compared to 6/66 (9%) in the no epinephrine cohort who survived (p=0.598). Among patients age <18 years, 9/81 (11%) in the epinephrine cohort survived compared to 19/52 (37%) in the no epinephrine cohort (p<0.001).

For multivariable analysis to assess the relative risk of survival, the adjustment variables included in the model were age, sex, mechanism, and initial heart rhythm. Stratified analyses specific to mechanism, age, and rhythm were performed; the related adjustment variable was removed from the model for these analyses. As shown in Figure 2, prehospital epinephrine was associated with significantly inferior survival to discharge in the following groups: overall, blunt and/or penetrating mechanism, blunt mechanism, age <18, and initial shockable rhythm. Among patients with penetrating mechanism and patients age ≥65, there was no significant difference identified.

Finally, time to event analyses were conducted using Cox proportional hazards models as shown in Figure 3. The same adjustment variables were used as in the previous multivariable models. Figure 3A shows adjusted and unadjusted model results among the overall cohort and the mechanism-specific

subcohorts; Figure 3B shows the resulting survival curve for the overall cohort in the adjusted analysis. In the overall cohort and the penetrating cohort, both adjusted and unadjusted models showed shorter survival among patients receiving prehospital epinephrine. In the blunt and/or penetrating mechanism cohort, a statistically significant difference was seen in the adjusted but not unadjusted analysis. In the blunt mechanism cohort, no significant difference was observed.

DISCUSSION

In this multicenter retrospective study of 1,631 patients who sustained prehospital traumatic cardiac arrest and received treatment at a level I or II trauma center, epinephrine did not improve hospital survival and was in many subgroups associated with inferior outcomes. Epinephrine was not associated with improved hospital survival in any of the cohorts assessed, including among patients ≥65 years, patients <18 years, patients with a shockable initial rhythm, or by category of injury mechanism. The data demonstrate early divergence in cumulative survival curves.

There are no nationwide guidelines to standardize prehospital approaches to traumatic cardiac arrest in the US, and practice is variable. A study of 9,565 EMS activations involving traumatic cardiac arrest from the National Emergency Medical Services Information System (NEMSIS) database found that epinephrine was administered in 60% of traumatic cardiac arrests (7). The authors also examined 35 publicly available state EMS protocols, finding that only 16 had a specific traumatic arrest protocol. Of these, three protocols recommended epinephrine administration and three protocols recommended against its use. There are little other data regarding epinephrine use for traumatic arrest from U.S. samples. An evaluation of the Resuscitation Outcomes Consortium Epistry-Trauma and PROPHET registries showed a 6.3 % survival to hospital discharge after traumatic arrest; ALS procedures did not improve survival. This study did not report on epinephrine use (8).

There is literature regarding epinephrine for traumatic arrest from other countries, although standard practices and prehospital care may differ substantially from the U.S. Japan maintains the All-Japan Utstein Registry, which is a nationwide, prospectively maintained, population-based registry of out-of-hospital cardiac arrests. An analysis of 1,030 trauma arrest patients in this dataset showed inferior survival to seven days among patients receiving epinephrine (1% vs 5%, also supported by a propensity matched analysis) – although this population differs from our study population in that 10% received epinephrine prehospital and 80% received epinephrine in the hospital (9). Another study of 5,204 patients from this registry with traumatic cardiac arrest from traffic collisions of whom 15% received prehospital epinephrine found that survival at one month was 1.5% in the epinephrine cohort compared to 0.9% in the no epinephrine cohort, but this difference was not significant in multivariable analysis (2). In that study, epinephrine use was associated with a higher likelihood of prehospital return of spontaneous circulation (ROSC) (2). A retrospective study of 410 patients sustaining traumatic out-of-hospital cardiac arrest in Qatar, in which 70% received epinephrine, also found that epinephrine was associated with lower odds of survival (10). ROSC in the ED occurred in 15% of the overall cohort, but only one patient in the epinephrine cohort survived. A retrospective cohort study from an EMS registry in Taipei, Taiwan did show improved outcomes with epinephrine for traumatic arrest, though the epinephrine vs no epinephrine groups differed substantially (11). A meta-analysis which includes four of the above described studies calculated a pooled OR of 0.61 (95% CI 0.11- 3.37) for in-hospital survival with epinephrine compared to no epinephrine, trend toward higher odds of ROSC (OR 4.67, 95% CI 0.66-32.81), and two hour short term survival with OR 1.41 (95% CI 0.53- 3.79) (12). Ultimately, these non-U.S. studies suggest that epinephrine does not substantially improve patient survival, though may improve ROSC or temporary survival. Overall, the data from our study align well with the existing

literature in our finding that epinephrine was not associated with improved outcomes.

Consideration of epinephrine's mechanisms of action and the body's physiologic response to injury provide plausibility to these study results. Vasoconstriction and tachycardia occur in the normal early compensatory process for progressive blood loss and hemorrhagic shock, mediated by the sympathetic nervous system, renin-angiotensin-aldosterone system, and endogenous catecholamines (13). Addition of exogenous epinephrine to further these mechanisms may provide limited additional benefit; several studies have shown worsened outcomes among trauma patients receiving early vasopressors and have, at minimum, recommended a thoughtful, nuanced approach to their use (13-18). Additionally, myocardial survival is dependent on coronary artery blood flow and oxygen delivery. With severe hypovolemic shock and subsequent traumatic cardiac arrest, minimal coronary artery blood flow occurs. The addition of exogenous epinephrine may induce more tachycardia, further increasing myocardial oxygen demand, with no ability to supply that demand. Basic science studies in animal models suggest that exogenous epinephrine likely worsens or does not improve myocardial function (19, 20).

We assessed a large, multi-institutional dataset and our results provide information specific to U.S. trauma systems. Our data align with and add to existing non-U.S. data to suggest that epinephrine is not associated with a durable improvement in survival after traumatic cardiac arrest. These results can inform prehospital traumatic arrest protocols and facilitate national guidelines specific to traumatic arrest.

LIMITATIONS

We acknowledge multiple limitations to this study. This was a retrospective study which was nonrandomized in design. This increases the likelihoods of confounding, selection, and survivor bias.

With regard to chart abstraction, there is potential for variability in reporting despite standard data definitions; inter-rater reliability was not formally assessed. Likewise, chart abstractors were not blinded to the hypothesis or study objectives. The patient cohort was ascertained on the basis of arrival at one of the included trauma centers, so patients sustaining traumatic cardiac arrest who died in the field are not studied. It is unknown whether epinephrine administration in these cases was associated with a higher or lower likelihood of surviving to arrive at a hospital, which could alter conclusions about the utility of epinephrine. Additionally, we lack discrete data on duration of arrest, whether/when ROSC was achieved, time to epinephrine administration, route of epinephrine administration, whether arrest was witnessed, bystander cardiopulmonary resuscitation (CPR), CPR duration, all of which could lead to unmeasured confounding, such as if the patients in the epinephrine cohort were those who did not regain pulses rapidly. Given that EMS protocols were not standardized across the study, there is risk for confounding by indication. We did observe variability in frequency of epinephrine use across receiving institutions, which does suggest that the outcome differences observed may be based on differences in regional approaches. Additionally, prehospital interventions such as use of blood products, intravenous fluids, tranexamic acid, tourniquets, airway maneuvers, pelvic binders, spinal motion restriction, were not ascertained and may influence clinical outcomes. Use of these may have differed across institutions and study timeframe, or have changed since the time of study data acquisition. Additional limitations include absence of data on patient comorbidities, although from a pragmatic standpoint this information would also not typically be available to the EMS clinicians initially assessing and making treatment decisions for a patient sustaining traumatic cardiac arrest. Similarly, advanced directives, which may influence inpatient decision-making, are not known. Standardized reporting of neurologic outcomes of survivors, and long-term functional post-discharge outcomes of survivors were not available in this dataset, but would be worthy to assess in the future. Ultimately, we expect that the results of this study should be broadly generalizable to locations with similar access to timely prehospital care as in our

study; however, further study is indicated regarding patients cared for in locations with prolonged access to definitive care, and locations with limited access to blood or an operating room.

CONCLUSIONS

In this multicenter retrospective study, epinephrine was not associated with improved survival following traumatic cardiac arrest, and in many subgroups, it was associated with inferior outcomes. For traumatic cardiac arrest, these results suggest that prehospital protocols should place Advanced Trauma Life Support tenets such as early blood product resuscitation, rapid hemorrhage control, and emergent evacuation to a trauma center as higher priority than the use of epinephrine.

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Figure 1: Traumatic cardiac arrest survival among patients receiving or not receiving epinephrine.

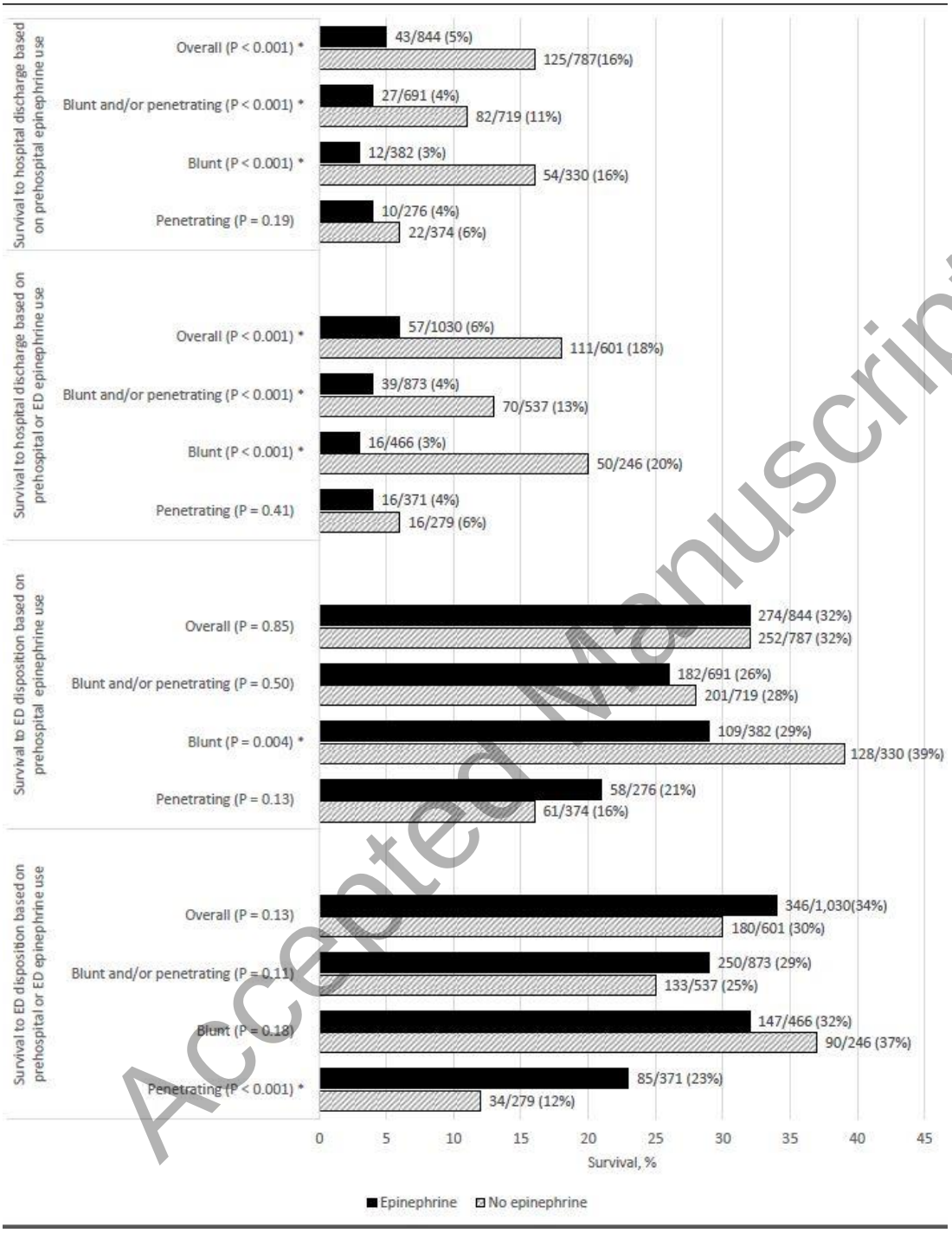

Figure 1 footnotes: The figure shows traumatic cardiac arrest survival at two timeframes (hospital discharge or ED disposition), with respect to two exposures (prehospital epinephrine or epinephrine in either prehospital or the ED). For prehospital epinephrine exposure, 844 patients received epinephrine

and 787 did not. For epinephrine either prehospital or in the ED, 1,030 patients received epinephrine and 601 did not. Blunt mechanism included motor vehicle crash, motorcycle crash, bicycle vs vehicle, pedestrian vs vehicle, fall from height. Penetrating mechanism included gunshot wound and stab wound. Blunt and/or penetrating mechanism included all patients in the blunt and penetrating cohorts, with the addition of assault. All three categories excluded ground level fall and "other". The X axis indicates the percentage of survivors within each cohort, with data labels showing the number of survivors, denominator, and percentage. Asterisks indicate $p<0.05$. Missingness was <1% in the variables used in this figure so was managed with casewise deletion.

Figure 2: Survival to hospital discharge based on use of prehospital epinephrine: multivariable analysis

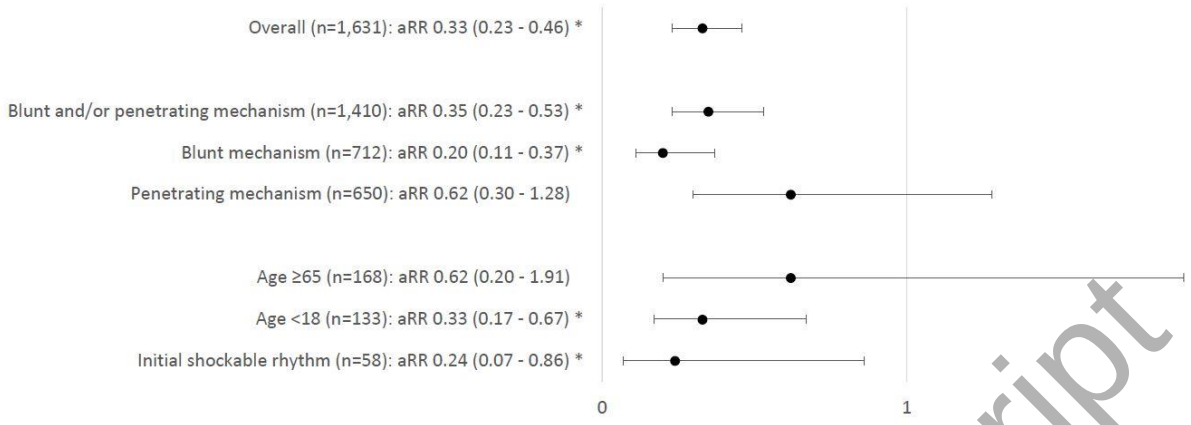

Figure 2 footnotes: The figure shows adjusted relative risk of survival to hospital discharge among patients with traumatic cardiac arrest. In the overall cohort of 1,631, 844 received epinephrine and 787 did not. Values shown are adjusted risk ratios (aRR) and 95% confidence intervals. Asterisks indicate $p<0.05$. ARR less than one indicates inferior survival with epinephrine. Adjustment variables were age, sex, mechanism, and initial heart rhythm. For stratified analyses specific to mechanism, age, and rhythm, the related adjustment variable was removed from the model. Blunt mechanism included motor vehicle crash, motorcycle crash, bicycle vs vehicle, pedestrian vs vehicle, fall from height. Penetrating mechanism included gunshot wound and stab wound. Blunt and/or penetrating mechanism included all patients in the blunt and penetrating cohorts, with the addition of assault. All three categories excluded ground level fall and "other". Missingness was <1% in the variables used in this figure so was managed with casewise deletion.

Figure 3: Survival based on use of prehospital epinephrine: time to event analysis

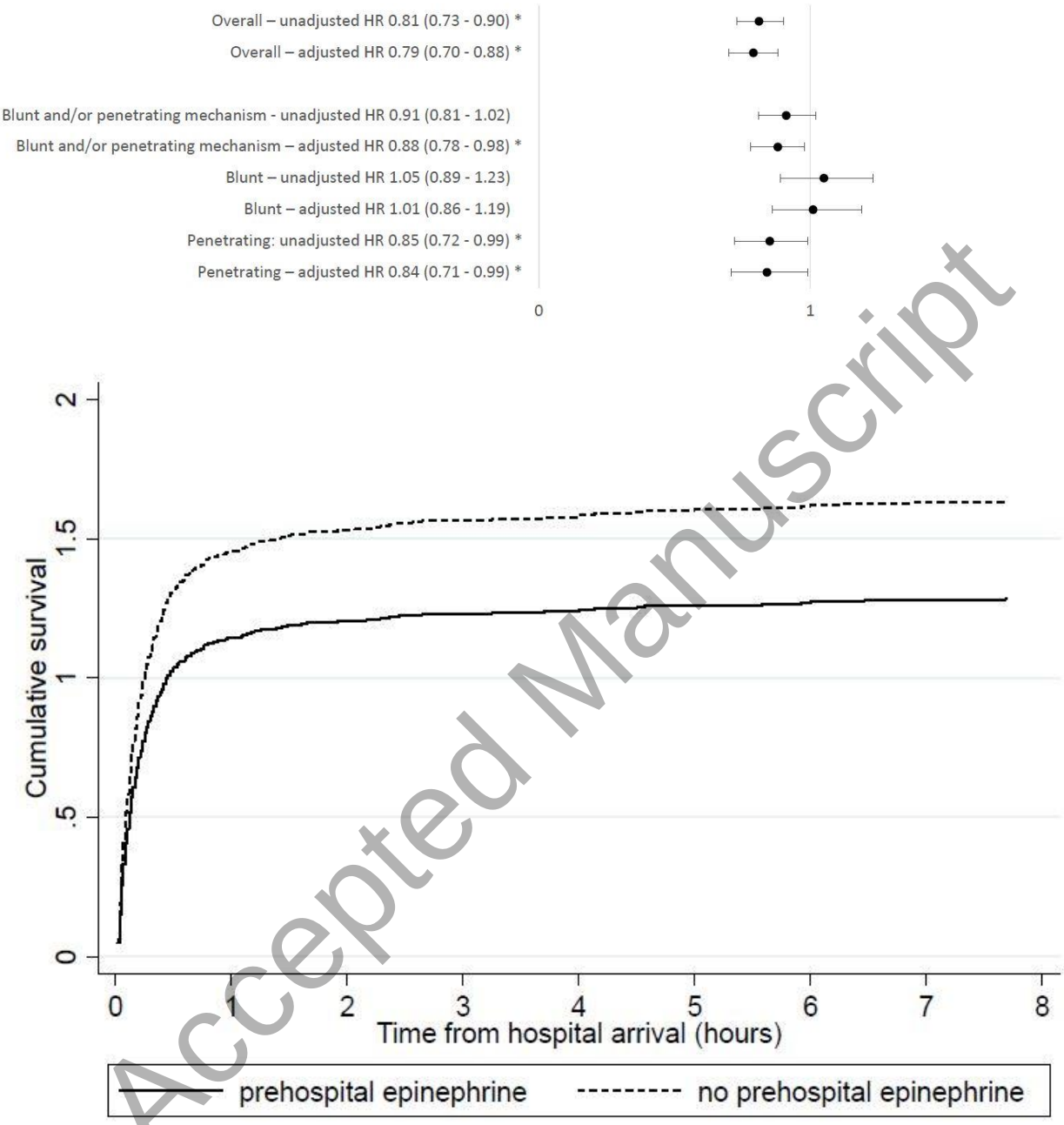

Figure 3 footnotes:

Figure 3A shows unadjusted and adjusted hazard ratios based on use of prehospital epinephrine based on Cox proportional hazards regression analyses among patients with traumatic cardiac arrest. In the overall cohort of 1,631, 844 received epinephrine and 787 did not. Values shown are adjusted or

unadjusted hazard ratios (HR) and 95% confidence intervals. Asterisks indicate $p<0.05$. Hazard ratios less than one indicate shorter survival with epinephrine. Adjustment variables were age, sex, and initial heart rhythm; injury mechanism was used as an adjustment variable for the overall cohort but not the mechanism-specific cohorts. Blunt mechanism included motor vehicle crash, motorcycle crash, bicycle vs vehicle, pedestrian vs vehicle, fall from height. Penetrating mechanism included gunshot wound and stab wound. Blunt and/or penetrating mechanism included all patients in the blunt and penetrating cohorts, with the addition of assault. All three categories excluded ground level fall and "other". Figure 3B shows the cumulative survival curve for the adjusted model for the overall cohort (the second series in Figure 3A). Missingness was <1% in variables used in these figures so was managed with casewise deletion.

Table 1: Patient characteristics and treatments

Patient characteristic	**No prehospital epinephrine (n=787)**	**Prehospital epinephrine (n=844)**	**Overall cohort (n=1,631)**	**Significance**
Age in years, median (interquartile range)	34 (24 – 49)	38 (24 – 54)	35 (24 – 51)	P = 0.003
Age category, n (%)				P < 0.001
≤10	18 (2%)	41 (5%)	59 (4%)	
>10 to ≤18	56 (7%)	49 (6%)	105 (6%)	
>18 to ≤ 45	483 (61%)	430 (51%)	913 (56%)	
>45 to ≤ 65	171 (22%)	230 (27%)	401 (25%)	
>65 to ≤ 75	31 (4%)	52 (6%)	83 (5%)	
>75	28 (4%)	42 (5%)	70 (4%)	
Female, n (%)	150 (19%)	185(22%)	335 (21%)	P = 0.15
Mechanism, n (%)				P < 0.001
Assault	15 (2%)	33 (4%)	48 (3%)	
Gunshot wound	335 (43%)	238 (28%)	573 (35%)	
Stab wound	39 (5%)	38 (5%)	77 (5%)	
Motor vehicle crash	108 (14%)	163 (19%)	271 (17%)	
Motorcycle crash	58 (7%)	52 (6%)	110 (7%)	
Bicycle vs vehicle	10 (1%)	14 (2%)	24 (1%)	
Pedestrian vs vehicle	93 (12%)	92 (11%)	185 (11%)	
Fall from height	61 (8%)	61 (7%)	122 (7%)	
Ground level fall	13 (2%)	31 (4%)	44 (3%)	
Other	55 (7%)	122 (14%)	177 (11%)	
Penetrating mechanism[a]	374 (47%)	276 (33%)	650 (40%)	P < 0.001
Blunt mechanism[b]	330 (42%)	382 (45%)	712 (44%)	P = 0.18
Blunt and/or penetrating mechanism[c]	719 (91%)	691 (82%)	1,410 (86%)	P < 0.001
Initial heart rhythm, n (%)				
Asystole	258 (33%)	293 (35%)	551 (343%)	P < 0.001
PEA	187 (24%)	300 (36%)	487 (30%)	
Sinus	290 (37%)	200 (24%)	490 (30%)	
Ventricular fibrillation	10 (1%)	33 (4%)	43 (3%)	
Ventricular tachycardia	8 (1%)	7 (1%)	15 (1%)	
Unknown	34 (4%)	11 (1%)	45 (3%)	
Treatments				
Minutes from scene arrival to ED arrival, median (interquartile range)	20 (11 – 29)	25 (16 – 38)	22 (15 – 33)	P < 0.001
Epinephrine in the ED, n (%)	186 (24%)	282 (33%)	468 (29%)	P < 0.001
Hospital interventions				P = 0.07
Laparotomy, n (%)	86 (11%)	70 (8%)	156 (10%)	
Thoracotomy, n (%)	35 (4%)	43 (5%)	78 (5%)	

Coronary angiography, n (%)	3 (0.4%)	6 (1%)	9 (1%)	
Intracranial monitoring, n (%)	21 (3%)	18 (2%)	39 (2%)	

Significance was assessed using Pearson's chi square testing or two-tailed t-tests, as appropriate.

Missingness was minimal and so was managed with casewise deletion. When heart rhythm was missing, it was analyzed as "unknown."

[a] penetrating mechanism included stab wound and gunshot wound.

[b] blunt mechanism included motor vehicle crash, motorcycle crash, bicycle vs vehicle, pedestrian vs vehicle, fall from height.

[c] included all patients in the blunt and penetrating cohorts, with the addition of assault.

Table 2: Survival to hospital discharge by patient characteristics

Patient characteristic	Survived, n/n (%)	Significance
Overall	168/1,631 (10%)	
Age category		P = 0.003
≤10	15/59 (25%)	
>10 to ≤18	15/105 (14%)	
>18 to ≤ 45	87/913 (10%)	
>45 to ≤ 65	39/401 (10%)	
>65 to ≤ 75	6/83 (7%)	
>75	6/70 (9%)	
Sex		P = 0.514
Male	128/1,295 (10%)	
Female	40/335 (12%)	
Mechanism, n (%)		P <0 .001
Assault	11/48 (23%)	
Gunshot wound	23/573 (4%)	
Stab wound	9/77 (12%)	
Motor vehicle crash	22/271 (8%)	
Motorcycle crash	6/110 (5%)	
Bicycle vs vehicle	2/24 (8%)	
Pedestrian vs vehicle	15/185 (8%)	
Fall from height	21/122 (17%)	
Ground level fall	12/44 (27%)	
Other	47/177 (27%)	
Penetrating mechanism[a]	32/650 (5%)	
Blunt mechanism[b]	66/712 (9%)	
Blunt and/or penetrating mechanism[c]	109/1,410 (8%)	
Initial heart rhythm		P < 0.001
Asystole	24/551 (4%)	
PEA	48/487 (10%)	
Sinus	82/490 (17%)	
Ventricular fibrillation	9/43 (11%)	
Ventricular tachycardia	2/15 (13%)	
Unknown	3/45 (7%)	

P values reflect within-group differences, assessed by Pearson's chi square testing. Missingness was <1% in the variables within this table so was managed with casewise deletion.

[a] penetrating mechanism included stab wound and gunshot wound.

[b] blunt mechanism included motor vehicle crash, motorcycle crash, bicycle vs vehicle, pedestrian vs vehicle, fall from height.

[c] included all patients in the blunt and penetrating cohorts, with the addition of assault.