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EAST Multicenter Trial on Targeted Temperature Management for Hanging-Induced Cardiac Arrest

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Abstract

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AUTHORSHIP

C.H.H. and D.M.S. participated in concept, design, data interpretation, and manuscript preparation. All authors participated in data acquisition and critical revisions of the manuscript.

DISCLOSURES

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BACKGROUND—We sought to determine the outcome of suicidal hanging and the impact of targeted temperature management (TTM) on hanging-induced cardiac arrest (CA) through an Eastern Association for the Surgery of Trauma (EAST) multicenter retrospective study.

METHODS—We analyzed hanging patient data and TTM variables from January 1992 to December 2015. Cerebral performance category (CPC) score of 1 or 2 was considered good neurologic outcome, while CPC of 3 or 4 was considered poor outcome. Classification and Regression Trees (CART) recursive partitioning was used to develop multivariate predictive models for survival and neurologic outcome.

RESULTS—Total of 692 hanging patients from 17 centers were analyzed for this study. Their overall survival rate was 77%, and the CA survival rate was 28.6%. The CA patients had significantly higher severity of illness and worse outcome than the non-CA patients. Of the 175 CA patients who survived to hospital admission, 81 patients (46.3%) received post-cardiac arrest TTM. The unadjusted survival of TTM CA patients (24.7% vs 39.4%, $p<0.05$) and good neurologic outcome (19.8% vs 37.2%, $p<0.05$) were worse than non-TTM CA patients. However, when subgroup analyses were performed between those with admission GCS of 3–8, the differences between TTM and non-TTM CA survival (23.8% vs 30.0%, $p=0.37$) and good neurologic outcome (18.8% vs 28.7%, $p=0.14$) were not significant. TTM implementation and post-cardiac arrest management varied between the participating centers. CART models identified variables predictive of favorable and poor outcome for hanging and TTM patients with excellent accuracy.

CONCLUSION—CA hanging patients had worse outcome than non-CA patients. TTM CA patients had worse unadjusted survival and neurologic outcome than non-TTM patients. These findings may be explained by their higher severity of illness, variable TTM implementation, and differences in post-cardiac arrest management. Future prospective studies are necessary to ascertain the effect of TTM on hanging outcome and to validate our CART models.

LEVEL OF EVIDENCE—Therapeutic study, level III; prognostic study, level III

Keywords

Hanging; cardiac arrest; targeted temperature management; therapeutic hypothermia; post-cardiac arrest prognostication

INTRODUCTION

Hanging is the second most common cause of suicide in the United States after firearms, claiming over 10,000 lives each year. The percentage of hanging amongst suicidal attempts increased from 19% in 2000 to 26% in 2010, while suicides caused by firearm decreased from 56% to 50% during the same time (1). Furthermore, the increases in suicidal hanging were greatest in females 10 to 24 years of age (2) and in the middle-aged population (3). Given the significant mortality of suicidal hanging (4, 5), these staggering statistics highlight a significant public health problem. To date, no treatment has been shown to improve the outcome of hanging patients.

Targeted temperature management (TTM) has been shown to improve the survival and neurologic outcome of shockable (6, 7) and nonshockable (8) cardiac arrest (CA) survivors. Previous animal (9) and neonatal studies (10) demonstrated that TTM is beneficial after hypoxic encephalopathy caused by asphyxia. Case reports (11, 12) and small retrospective studies (13–17) have also shown the potential benefits of TTM after asphyxial CA. However, the randomized TTM trials to date have mainly focused on shockable rhythms and excluded asphyxial arrest (6, 7, 18, 19). Therefore, the role of TTM in hanging-induced CA management remains unknown.

We previously showed in a single-center retrospective study that hanging patients who suffered from CA had significantly higher severity of illness and worse outcome than those who did not suffer from CA (20). We demonstrated that post-cardiac arrest TTM was feasible for hanging patients, but our study did not have enough power to detect outcome differences between the TTM and non-TTM hanging patients. As such, we sought to further investigate the outcome of suicidal hanging and the impact of TTM on hanging-induced CA through an Eastern Association for the Surgery of Trauma (EAST) multicenter retrospective study. We hypothesized that a larger cohort size would allow us to identify outcome predictors and detect TTM-associated outcome differences in hanging patients.

PATIENT AND METHODS

Seventeen centers participated in this multicenter retrospective study (see Supplemental Table 1, Supplemental Digital Content, <http://links.lww.com/TA/B161>). Data from 692 patients with hanging as injury type were de-identified and entered into a secured American Association for the Surgery of Trauma (AAST) online data portal (<https://secure.myispartner.com/Trauma/login.aspx>). We collected patient demographics, prehospital and admission data, Utstein variables (21), laboratory and diagnostics studies, TTM variables and complications, and discharge outcome from January 1992 to December 2015. The first hanging patient was identified in 1992, while the first TTM patient was from 2005. All 692 patients were analyzed for overall patient demographic and outcome (Table 1). We then excluded 24 patients who were dead on arrival (DOA) from subsequent analyses. DOA was defined as those who were pulseless on arrival and never achieved return of spontaneous circulation (ROSC) despite resuscitative efforts. Cerebral anoxia was defined as radiologic evidence of anoxia on brain computed tomography (CT) scans. Cerebral performance category (CPC) score of 1 or 2 was considered good neurologic outcome, while CPC of 3 or 4 was considered poor outcome (22). This study was approved by the Institutional Review Boards at the participating centers.

We used Chi-square tests to compare categorical variables, and their effect sizes were expressed as frequencies (n) and percentages (%). We used Mann-Whitney U tests to compare continuous variables, and their effect sizes were expressed as medians and interquartile ranges (IQR). A two-sided p-value < 0.05 indicated statistical significance. These statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC) and SPSS 25 (IBM Corp., Armonk, NY).

We used Classification and Regression Trees (CART) recursive partitioning to develop multivariate predictive models for survival and good neurological outcome. All available pre-hospital and admission data were included in the CART model development. We used the Gini coefficient to determine the best split. To build the most optimal trees, we cross-validated each tree 10 times using a boot-strapping technique, in which the model was developed using 90% of the patients and then tested using patients not included in the tree development. The most stable trees were selected (23–27). Areas under the receiver operating characteristics (AUROCC) with 95% confidence interval (CI) were determined to evaluate model accuracy. Because the application of TTM was not randomly assigned to our study population, and patients who received TTM might have differed inherently from those who did not, we developed separate CART models by forcing the first split to be on TTM. As prior studies have defined medical futility as likelihood for success of less than 3% (28), we predefined 3% as very low, >3 to 25% as low, >25 to 75% as average, >75 to <97% as high, and 97% as very high probability for survival or good neurologic outcome. The CART analyses were performed with SPM Salford Predictive Modeler (Salford Systems, San Diego, CA).

RESULTS

Total of 692 hanging patients from 17 centers were analyzed for this study. Their mean age was 32 years (IQR 24–43); 80.5% were male, and 68.4% were white. Their overall survival rate was 77%, and the survival rate for CA patients was 28.6%. A significant portion of hanging patients had psychiatric disorders (58.2%), prior suicide attempt (23.1%), alcohol abuse (22.7%), tobacco use (22.3%), and drug abuse (14.5%). The most frequent injury locations were private residence (61%) and prison (24%; Table 1). Out of 692 hanging patients, 199 (28.8%, including 24 DOA) suffered from CA. Of the 175 CA patients who survived to hospital admission, 81 patients (46.3%) received post-cardiac arrest TTM, while 16 out of the 493 non-CA patients (3.2%) received TTM (Figure 1).

The CA patients had significantly higher severity of illness and worse outcome than non-CA patients. The CA patients had higher Injury Severity Score (ISS), higher Abbreviated Injury Scale (AIS) Head, lower systolic blood pressure (SBP) and heart rate, lower admission temperature, and higher lactate and base excess. The CA patients also had higher incidences of cervical spine bony and spinal cord injuries, blunt cerebrovascular injuries, and upper airway injuries. Finally, they had worse prehospital and admission Glasgow Coma Score (GCS), higher incidence of cerebral anoxia on CT scans (54.3% vs 11.4%, $p<0.001$), worse survival (28.6% vs 96.6%, $p<0.001$), and fewer good neurologic outcome (25.6% vs 94.3%, $p<0.001$) at hospital discharge compared to the non-CA patients. The length of survival after hospital discharge were largely unknown (70.7% unknown; Table 1).

The CA patients who received TTM had higher severity of illness than the non-TTM CA patients. The TTM CA patients had worse prehospital and admission GCS. All TTM CA patients had prehospital GCS 3–8 compared to 85.1% of non-TTM CA patients ($p<0.01$), and 98.8% of TTM vs 85.1% non-TTM CA patients had admission GCS 3–8 ($p<0.01$). In addition, the TTM CA patients also had longer time to ROSC and more nonshockable rhythm than the non-TTM patients (Table 2a). However, 38.9% of initial rhythm and 44% of

time to ROSC were unknown in this study (see Supplemental Table 4, Supplemental Digital Content, <http://links.lww.com/TA/B161>).

The TTM CA patients had worse unadjusted survival than the non-TTM CA patients (24.7% vs 39.4%, $p<0.05$), and fewer TTM CA patients were discharged with good neurologic outcome (19.8% vs 37.2%, $p<0.05$; Table 2b). However, when subgroup analyses were performed between those with admission GCS of 3–8 from both groups, the differences between TTM and non-TTM CA survival (23.8% vs 30.0%, $p=0.37$) and good neurologic outcome (18.8% vs 28.7%, $p=0.14$) were not significant. The TTM CA patients had longer hospital length of stay (LOS), intensive care unit LOS, and time on mechanical ventilation. More TTM CA patients became organ donors than the non-TTM patients (52.5% vs 31.6%, $p<0.05$). More TTM patients died from withdrawal of life-sustaining measures (72.1% vs 26.3%, $p<0.001$), whereas more non-TTM CA patients died from brain death (52.6% vs 27.9%, $p<0.001$; Table 2b).

The 16 non-CA patients who received TTM also had higher severity of illness and worse outcome compared to the 477 non-TTM non-CA patients. The TTM non-CA patients had higher median ISS, AIS Head, worse prehospital GCS, and worse admission GCS (see Supplemental Table 2a, Supplemental Digital Content, <http://links.lww.com/TA/B161>). There were also more TTM non-CA patients with cerebral anoxia (50% vs 10.1%, $p<0.001$). The TTM non-CA patients had worse survival to hospital discharge (75% vs 97.3%, $p<0.001$) and fewer discharged with good neurologic outcome (68.8% vs 95.2%, $p<0.001$; see Supplemental Table 2b, Supplemental Digital Content, <http://links.lww.com/TA/B161>).

TTM was most frequently initiated with cold saline (44.3%) and external cooling device (59.8%). The median time from ROSC to TTM induction was 180 minutes (IQR 80–280), and the median time from TTM induction to target temperature was 160 minutes (IQR 103–303). However, 61.7% of time from ROSC to TTM induction and 28.9% of time from TTM induction to target temperature were unknown (see Supplemental Table 4, Supplemental Digital Content, <http://links.lww.com/TA/B161>). The median minimum target temperature was 33.0°C (IQR 32.0–33.8) and maximum target temperature was 34°C (IQR 34–36). The median duration at target temperature was 24 hours (IQR 23–24), and the median rate of rewarming was 0.48°C/hour (IQR 0.25–0.50). 40.2% of TTM patients were known to have maintenance of normothermia after rewarming, with median normothermia duration of 24 hours (IQR 7.5–48.0). The most common complications were electrolyte derangement (39.2%), seizure (27.8%), pneumonia (25.8%), and hemodynamic instability (23.7%; see Supplemental Table 3, Supplemental Digital Content, <http://links.lww.com/TA/B161>).

We developed CART models to identify variables that best predict the survival and neurologic outcome of all hanging patients (Figures 2a and 2b). The CA patients with admission GCS > 6 had very high probability of survival (100%, AUROCC = 0.926; Figure 2a). In addition, the CA patients with prehospital GCS verbal > 2 had very high probability of good neurologic outcome (100%, AUROCC = 0.925; Figure 2b). The non-CA hanging patients with lowest SBP > 86 mmHg within first 6 hours had very high probability of survival (97.4%, AUROCC = 0.926). For the non-CA patients who had SBP > 86 within first 6 hours, those with age < 29 years had very high probability of survival (100%, AUROCC =

0.926; Figure 2a). The non-CA patients with ISS ≥ 19 had very high probability of good neurologic outcome (97.6%, AUROCC = 0.925; Figure 2b).

Because TTM was not randomly assigned in this study, we also developed separate CART models using TTM as the first split to predict the outcome of TTM hanging patients. Figure 3a showed that TTM patients with time to ROSC > 10 minutes and admission GCS ≤ 4 had low probability of survival (4.3%, AUROCC = 0.95). For the neurologic outcome of TTM hanging patients, those with time to ROSC > 7 minutes, as well as admission GCS ≤ 4 and cerebral anoxia had very low probability of good neurologic outcome (0%; AUROCC = 0.937; Figure 3b). We then developed separate CART models to predict the outcome of TTM CA patients. The TTM CA patients who had admission lactate > 7 mmol/L had very low probability of survival (3%, AUROCC = 0.911, 95% CI 0.863–0.960; Figure 4a). While time to ROSC > 7 minutes and admission base excess > -9 mEq/L were predictive of poor neurologic outcome for the TTM CA patients (Figure 4b), these outcomes did not meet our predefined 3% for futility and the model was not as robust (AUROCC = 0.864).

DISCUSSION

The results of this EAST multicenter retrospective study confirmed that CA hanging patients had higher severity of illness and worse outcome at hospital discharge than the non-CA patients. Our data also highlighted the significant societal burden imposed by suicidal hanging in the United States, with median age of 32 years, 77% overall survival, and 28.6% CA survival. Our study further demonstrated the high incidence of psychiatric disorders, prior suicide attempts, and polysubstance abuse in hanging patients. These findings will help to identify vulnerable populations for suicide prevention and intervention.

Our data showed that hanging patients who received TTM had worse survival and neurologic outcome than non-TTM patients. These findings can be explained by several factors. The CA and non-CA patients who received TTM in this study had higher severity of illness, as demonstrated by their higher injury severity scores, prehospital and admission GCS, and incidence of cerebral anoxia. TTM was likely applied to these sicker patients in hope to improve their outcome. The association between the severity of illness and TTM CA patient outcome was supported by the lack outcome differences between the patients with admission GCS 3–8. It was possible that the protective effect of TTM might have shifted the outcome of the more critically ill CA patients toward that of the non-TTM CA patients with similar severity of illness, resulting in the null effects observed in the subgroup analyses.

Another explanation for the worse outcome of TTM patients was the variability in TTM implementation and post-cardiac arrest management. The time from ROSC to TTM induction (180 minutes [IQR 80–280]) and from TTM induction to target temperature (160 minutes [IQR 103–303]) were quite variable and prolonged in this study, with 61.7% and 28.9% unknown data, respectively (see Supplemental Table 4, Supplemental Digital Content, <http://links.lww.com/TA/B161>). Animal studies have shown that earlier initiation of TTM and time to target temperature of within 4 hours after ROSC can improve survival with good neurologic function (29). However, these findings have not been consistently observed in human subjects. In recent studies, shorter time to target temperature was associated with

worse outcome (8, 30, 31), likely due to more significant brain injury and impaired thermoregulation in the shorter time to target temperature group. In addition, whether TTM patients were maintained in normothermia after rewarming was largely unknown in our study (66% unknown; see Supplemental Table 4, Supplemental Digital Content, <http://links.lww.com/TA/B161>). Pyrexia has been associated with worse outcome in post-cardiac arrest survivors (32, 33). As such, knowing whether the TTM patients were maintained in normothermia after rewarming would be critical for outcome analysis. Finally, we did not collect information regarding the hemodynamic goals, ventilator management, and sedative/paralytic use of these patients. It is possible that the different TTM implementation strategies and post-cardiac arrest management nullified any protective effect of temperature management.

Another contributing factor to TTM outcome in this study was post-cardiac arrest prognostication. Although we collected data regarding normothermia after rewarming, hospital LOS, CT brain results, and causes of death, it was unclear whether the participating centers followed consistent prognostication protocols throughout the study period. It is also likely the post-cardiac arrest prognostication varied between the centers. Post-cardiac arrest prognostication is best performed as a multimodal approach that includes clinical examination, electroencephalography (EEG), somatosensory evoked potential (SSEP), biomarkers, and brain imaging (34, 35). The timing of prognostication for the TTM patients is also critical. Recent retrospective studies have shown TTM to be associated with variable delay in awakening beyond 3 days after ROSC or rewarming (36–39). In addition to hypothermia, factors such as older age, renal insufficiency, and shock were also independent predictors of delayed awakening after cardiac arrest (37, 38). As the TTM CA patients in this study had median ICU LOS of 4 days (IQR 3–7), it is possible that some patients might have had premature prognostication and withdrawal of life-sustaining measures, which led to their seemingly worse survival due to self-fulfilling prophecy.

The benefit of TTM for nonshockable CA outcome is less clear, and it is possible that TTM may be harmful to survivors who sustained nonshockable CA. The randomized TTM trials to date have largely focused on shockable rhythms, and the expansion of TTM indication to nonshockable CA had been based on smaller retrospective studies (8). Although there was significant unknown initial rhythm, we assume that most hanging-induced CA were nonshockable based on prior studies (17, 40). In a propensity matched analysis of 1,568 in-hospital CA survivors from the Get With the Guideline-Resuscitation (GWTG-R) Registry, Chan et al. found that TTM was associated with worse outcome. Although these differences held true for both the shockable and nonshockable rhythms, the majority of patients in this study had nonshockable rhythms (41). A multicenter, randomized, controlled study (HYPERION Trial) is currently ongoing to assess whether TTM is beneficial to comatose patients resuscitated after nonshockable CA (42).

Our data suggest that the complication rates associated with TTM in the hanging population were comparable to those of larger TTM trials. The most common complications in this study were electrolyte derangement (39.2%), seizure (27.8%), pneumonia (25.8%), and hemodynamic instability (23.7%). In the TTM Trial with 473 patients randomized to 33°C, 93% of patients had at least one complication. There were 19% with hypokalemia, 44% with

hypophosphatemia, 52% with pneumonia, 28% with myoclonic seizures, 9.1% with recurrent CA, and 5.2% with bradycardia that required pacing (19). Kirkegaard et al. found similar complication rates in 176 patients randomized to receive 24-hour TTM at $33 \pm 1^\circ\text{C}$ (18). Taken together, our data suggest that TTM application to hanging patients had acceptable complication rates.

We utilized CART to develop predictive models for survival and neurologic outcome with excellent accuracy. CART has multiple advantages over other analytic methods such as multivariate logistic regression. It is inherently nonparametric, and thus make no assumptions regarding the underlying distribution of the predictive values (26, 27). Furthermore, it can handle missing data and highly skewed or multimodal variables by repeated sampling techniques (43). Prior studies have utilized CART to develop useful models of CA outcome (26, 27, 43–46). We identified variables that can predict favorable survival and neurologic outcome of all hanging patients. Furthermore, we identified variables that were predictive of poor outcome in TTM patients. These poor outcome predictors may help guide families with care decisions, as significant resource utilization and emotional burden are often associated with post-cardiac arrest care. Prior smaller retrospective studies have also identified SBP (47), admission GCS (5, 16, 47), time to ROSC (16), cerebral anoxia, and ISS (47) as predictors of hanging outcome.

This study has several limitations. It is a retrospective study with its inherent biases. Although this is the largest hanging outcome study from the United States, our TTM patient cohort size was still relatively small. Significant unknown data regarding TTM variables precluded us from definitive analyses of TTM implementation and post-cardiac arrest care. Thus, it is difficult to ascertain the true effect of TTM on hanging-induced CA outcome without performing a multicenter randomized controlled study with more consistent management protocols and metrics database. Although we chose 3% as the cutoff for medical futility, more research is needed to identify the optimal decision algorithm preferred by patients, families, and healthcare providers. As the CART models may be unstable due to variable correlation and random fluctuation in data (44), our models will need to be prospectively validated to confirm their accuracy. Finally, although we were not able to evaluate long-term outcome due to unavailable data, previous studies have shown that CPC at hospital discharge correlated well with the long-term outcome of CA patients (48–50).

CONCLUSION

Our data showed that hanging-induced CA patients had worse outcome than non-CA patients. Furthermore, our data suggest that hanging patients with higher severity of illness were more likely to receive TTM. TTM patients had worse unadjusted survival and neurologic outcome at hospital than the non-TTM patients. These findings may be explained by their higher severity of illness, variable TTM implementation, and differences in post-cardiac arrest management and prognostication. Our CART models identified variables predictive of favorable and poor outcome. Future prospective studies with more comprehensive CA database are necessary to ascertain the effect of TTM on hanging outcome and to validate the CART models.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Figure 1.
Outcome of hanging patients. Good outcome represented patients with CPC score of 1 or 2.
Poor outcome represented patients with CPC score of 3 or 4.

Figure 2a.

Figure 2b.

Figure 2.

Figure 2a. Classification and Regression Trees predictive model for survival to hospital discharge of all hanging patients. AUROCC = 0.926 (95% CI 0.898–0.955, $p < 0.05$).

Figure 2b. Classification and Regression Trees predictive model for good neurologic outcome at hospital discharge of all hanging patients. AUROCC = 0.925 (95% CI 0.899–0.952, $p < 0.05$).

Figure 3a.

Figure 3b.

Figure 3.

Figure 3a. Classification and Regression Trees predictive model for survival to hospital discharge of all TTM hanging patients. AUROCC = 0.950 (95% CI 0.932–0.968, $p < 0.01$).

Figure 3b. Classification and Regression Trees predictive model for good neurologic outcome at hospital discharge of all TTM hanging patients. AUROCC = 0.937 (95% CI 0.915–0.959, $p < 0.05$).

Figure 4a.

Figure 4b.

Figure 4.

Figure 4a. Classification and Regression Trees predictive model for survival to hospital discharge of TTM CA hanging patients. AUROCC = 0.911 (95% CI 0.863–0.960, $p < 0.05$).

Figure 4b. Classification and Regression Trees predictive model for good neurologic outcome at hospital discharge of TTM CA hanging patients. AUROCC = 0.864 (95% CI 0.795–0.932, $p < 0.05$).

Table 1**Hanging Patient Demographics & Outcome**

	Overall (n=692)	CA (n=199)	Non-CA (n=493)	<i>p</i>
Age, median years (IQR)	32 (24–43)	31 (24–43)	32 (25–43)	0.74
Male, n (%)	557 (80.5)	160 (80.4)	397 (80.5)	0.97
White, n (%)	473 (68.4)	143 (71.9)	330 (66.9)	0.44
Pre-morbid conditions, n (%)				
Cardiac disease	22 (3.2)	4 (2.0)	18 (3.7)	0.27
Diabetes	23 (3.3)	5 (2.5)	18 (3.7)	0.45
Alcohol	157 (22.7)	37 (18.6)	120 (24.3)	0.10
Tobacco	154 (22.3)	33 (16.6)	121 (24.5)	<0.05
Drug abuse	100 (14.5)	27 (13.6)	73 (14.8)	0.68
Psychiatric disorder	403 (58.2)	103 (51.8)	300 (60.9)	<0.05
Prior suicide	160 (23.1)	36 (18.1)	124 (25.2)	<0.05
Unknown	66 (9.5)	41 (20.6)	25 (5.1)	<0.001
ISS, median (IQR)	5 (1–10)	16 (4–26)	3 (1–9)	<0.001
AIS Head, median (IQR)	3 (2–5)	5 (3–5)	3 (1–3)	<0.001
AIS Neck, median (IQR)	1 (1–1)	1 (1–2)	1 (1–1)	0.08
Location of injury, n (%)				
Prison	166 (24.0)	50 (25.1)	116 (23.5)	0.49
Private residence	422 (61.0)	127 (63.8)	295 (59.8)	
Public building	33 (4.8)	9 (4.5)	24 (4.9)	
Psychiatric institution	18 (2.6)	3 (1.5)	15 (3.0)	
Other	39 (5.6)	7 (3.5)	32 (6.5)	
Unknown	14 (2.0)	3 (1.5)	11 (2.2)	
Prehospital GCS, n (%)				
3 to 8	371 (53.6)	184 (92.5)	187 (37.9)	<0.001
9 to 12	30 (4.3)	0 (0)	30 (6.1)	
13 to 15	184 (26.6)	7 (3.5)	177 (35.9)	
Unknown	107 (15.5)	8 (4.0)	99 (20.1)	
Admission GCS, n (%)				
3 to 8	391 (56.5)	180 (90.5)	211 (42.8)	<0.001
9 to 12	36 (5.2)	3 (1.5)	33 (6.7)	
13 to 15	234 (33.8)	9 (4.5)	225 (45.6)	
Unknown	31 (4.5)	7 (3.5)	24 (4.9)	
Admission vital signs				
SBP, median mmHg (IQR)	132 (116–148)	123 (102–143)	133 (120–149)	<0.001
HR, median beats/min (IQR)	97 (82–115)	107 (85–130)	95 (80–111)	<0.001
SpO2, median (IQR)	100 (98–100)	100 (97–100)	100 (98–100)	0.34
Temperature, median °C (IQR)	36.6 (36.0–36.9)	36.1 (34.9–36.8)	36.6 (36.2–37.0)	<0.001

	Overall (n=692)	CA (n=199)	Non-CA (n=493)	p
Lowest SBP in initial 6 hours, median mmHg (IQR)	109 (96–120)	100 (83–114)	111 (101–122)	<0.001
Admission labs				
pH, median (IQR)	7.33 (7.22–7.40)	7.23 (7.12–7.35)	7.36 (7.30–7.41)	<0.001
Lactate, median mmol/L (IQR)	3.3 (1.8–6.5)	5.4 (3.2–9.7)	2.7 (1.6–4.9)	<0.001
Base Excess, median mEq/L (IQR)	−4.3 (−9.4, −1.2)	−8.6 (−13.0, −3.9)	−2.8 (−5.9, −0.1)	<0.001
Cerebral anoxia, n (%)	164 (23.7)	108 (54.3)	56 (11.4)	<0.001
Cervical spine bony injury, n (%)	20 (2.9)	7 (3.5)	13 (2.6)	<0.001
Cervical spinal cord injury, n (%)	7 (1.0)	4 (2.0)	3 (0.6)	<0.001
Blunt cerebrovascular injury, n (%)	42 (6.1)	14 (7.0)	28 (5.7)	<0.001
Upper airway injury, n (%)	37 (5.3)	12 (6.0)	25 (5.1)	<0.001
Discharge GCS, n (%)				
3 to 8	137 (19.8)	130 (65.3)	7 (1.4)	<0.001
9 to 12	14 (2.0)	4 (2.0)	10 (2.0)	
13 to 15	449 (64.9)	49 (24.6)	400 (81.1)	
Unknown	92 (13.3)	16 (8.0)	76 (15.4)	
Survival, n (%)	533 (77.0)	57 (28.6)	476 (96.6)	<0.001
Discharged with good neurologic outcome, n (%)	516 (74.6)	51 (25.6)	465 (94.3)	<0.001
Length of survival after discharge, n (%)				
<1 month	6 (0.9)	2 (1.0)	4 (0.8)	<0.005
1 to 6 months	12 (1.7)	2 (1.0)	10 (2.0)	
6 month to 1 year	3 (0.4)	1 (0.5)	2 (0.4)	
>1 year	182 (26.3)	33 (16.6)	149 (30.2)	
Unknown	489 (70.7)	161 (80.9)	328 (66.5)	

Table 2a**TTM vs Non-TTM Cardiac Arrest Patient Demographics**

	Overall (n=175)	TTM (n=81)	Non-TTM (n=94)	<i>p</i>
Age, median years (IQR)	33 (24–43)	34 (25–43)	32 (23–42)	0.74
Male, n (%)	142 (81.1)	65 (80.2)	77 (81.9)	0.78
White, n (%)	130 (74.3)	64 (79.0)	66 (70.2)	0.22
Pre-morbid conditions, n (%)				
Cardiac disease	4 (2.3)	1 (1.2)	3 (3.2)	0.39
Diabetes	5 (2.9)	1 (1.2)	4 (4.3)	0.23
Alcohol	35 (20.0)	18 (22.2)	17 (18.1)	0.50
Tobacco	33 (18.9)	16 (19.8)	17 (18.1)	0.78
Drug abuse	26 (14.9)	15 (18.5)	11 (11.7)	0.21
Psychiatric disorder	95 (54.3)	51 (63.0)	44 (46.8)	<0.05
Prior suicide	32 (18.3)	15 (18.5)	17 (18.1)	0.94
Unknown	30 (17.1)	11 (13.6)	19 (20.2)	0.25
ISS, median (IQR)	17 (5–26)	25 (9–26)	10 (1–26)	0.08
AIS Head, median (IQR)	5 (3–5)	5 (3–5)	5 (3–5)	0.78
AIS Neck, median (IQR)	1 (1–2)	1 (1–1)	1 (1–2)	0.42
Location of injury, n (%)				
Prison	48 (27.4)	22 (27.2)	26 (27.7)	0.81
Private residence	108 (61.7)	51 (63.0)	57 (60.6)	
Public building	8 (4.6)	3 (3.7)	5 (5.3)	
Psychiatric institution	1 (0.6)	1 (1.2)	0 (0)	
Other	7 (4.0)	4 (4.9)	3 (3.2)	
Unknown	3 (1.7)	0 (0)	3 (3.2)	
Total scene time, median minutes (IQR)	19 (12–37)	25 (13–42)	15 (10–29)	0.06
Total transport time, median minutes (IQR)	13 (10–27)	14 (10–34)	13 (9–26)	0.50
Transport from another facility, n (%)	67 (38.3)	33 (40.7)	34 (36.2)	0.54
Time at other facility, median hours (IQR)	2.0 (1.0–2.7)	1.7 (0.9–2.7)	2.1 (1.1–2.8)	0.43
Initial cardiac rhythm, n (%)				
Asystole	55 (31.4)	29 (35.8)	26 (27.7)	<0.001
Pulseless Electrical Activity	46 (26.3)	33 (40.7)	13 (13.8)	
Ventricular Fibrillation	6 (3.4)	3 (3.7)	3 (3.2)	
Unknown	68 (38.9)	16 (19.8)	52 (55.3)	
Time to ROSC, median minutes (IQR)	10.5 (4.8–25.0)	20 (7–28)	8 (3–15)	<0.005
Total hanging time, median minutes, (IQR)	15 (10–24)	15 (10–25)	15 (6–23)	0.63
Bystander CPR, n (%)	127 (72.6)	62 (76.5)	65 (69.1)	<0.01
Prehospital GCS, n (%)				
3 to 8	161 (92.0)	81 (100.0)	80 (85.1)	<0.01
9 to 12	0 (0)	0 (0)	0 (0)	

	Overall (n=175)	TTM (n=81)	Non-TTM (n=94)	<i>p</i>
13 to 15	7 (4.0)	0 (0)	7 (7.4)	
Unknown	7 (4.0)	0 (0)	7 (7.4)	
Admission GCS, n (%)				
3 to 8	160 (91.4)	80 (98.8)	80 (85.1)	<0.01
9 to 12	3 (1.7)	0 (0)	3 (3.2)	
13 to 15	9 (5.1)	0 (0)	9 (9.6)	
Unknown	3 (1.7)	1 (1.2)	2 (2.1)	
Admission vital signs				
SBP, median mmHg (IQR)	123 (102–143)	131 (106–146)	120 (99–138)	<0.05
HR, median beats/min (IQR)	107 (85–130)	109 (92–128)	103 (81–132)	0.15
SpO2, median (IQR)	100 (97–100)	100 (97–100)	100 (98–100)	0.62
Temperature, median °C (IQR)	36.2 (34.9–36.8)	36.0 (34.7–36.7)	36.3 (35.4–37.0)	0.06
Lowest SBP in initial 6 hours, median mmHg (IQR)	100 (83–114)	100 (85–116)	100 (82–114)	0.66
Admission labs				
pH, median (IQR)	7.24 (7.13–7.35)	7.23 (7.15–7.31)	7.26 (7.12–7.39)	0.27
Lactate, median mmol/L (IQR)	5.3 (3.2–9.9)	5.7 (3.2–11.0)	5.1 (2.7–9.0)	0.31
Base Excess, median mEq/L (IQR)	−8.0 (−13.0, −3.8)	−8.8 (−13.0, −5.0)	−7.9 (−13.0, −2.6)	0.13

Table 2b

TTM vs Non-TTM Cardiac Arrest Patient Outcome

	Overall (n=175)	TTM (n=81)	Non-TTM (n=94)	p
Cerebral anoxia, n (%)	107 (61.1)	52 (64.2)	55 (58.5)	0.43
Cervical spine bony injury, n (%)	7 (4.0)	0 (0)	7 (7.4)	<0.01
Cervical spinal cord injury, n (%)	4 (2.3)	1 (1.2)	3 (3.2)	0.22
Blunt cerebrovascular injury, n (%)	14 (8.0)	8 (9.9)	6 (6.4)	0.35
Upper airway injury, n (%)	12 (6.9)	5 (6.2)	7 (7.4)	0.76
Tracheostomy, n (%)	6 (3.4)	3 (3.7)	3 (3.2)	0.85
Surgical feeding access, n (%)	11 (6.3)	6 (7.4)	5 (5.3)	0.47
Hospital LOS, median days (IQR)	4 (2–7)	5 (3–8)	3 (2–5)	<0.001
ICU LOS, median days (IQR)	3 (2–6)	4 (3–7)	2 (1–4)	<0.001
Duration of mechanical ventilation, median days (IQR)	3 (1–5)	4 (3–7)	2 (1–4)	<0.001
Total number of days alive in hospital, median days (IQR)	3 (2–5)	4 (3–7)	2 (1–4)	<0.001
Organ donor, n (%) *	50 (42.4)	32 (52.5)	18 (31.6)	<0.05
Cause of death, n (%) *				
Brain death	47 (39.8)	17 (27.9)	30 (52.6)	<0.001
Withdrawal of lifesustaining measures	59 (50.0)	44 (72.1)	15 (26.3)	
Other	6 (5.1)	0 (0)	6 (10.5)	
Unknown	6 (5.1)	0 (0)	6 (10.5)	
Discharge destination, n (%)				
Home	9 (5.1)	4 (4.9)	5 (5.3)	0.07
Inpatient Psychiatry	22 (12.6)	5 (6.2)	17 (18.1)	
Prison	14 (8.0)	4 (4.9)	10 (10.6)	
Morgue	118 (67.4)	61 (75.3)	57 (60.6)	
Rehab/SNF/Other	12 (6.9)	7 (8.6)	5 (5.3)	
Unknown	0 (0)	0 (0)	0 (0)	
Discharge GCS, n (%)				
3 to 8	111 (63.4)	62 (76.5)	49 (52.1)	<0.005
9 to 12	4 (2.3)	1 (1.2)	3 (3.2)	
13 to 15	49 (28.0)	18 (22.2)	31 (33.0)	
Unknown	11 (6.3)	0 (0)	11 (11.7)	
Survival, n (%)	57 (32.6)	20 (24.7)	37 (39.4)	<0.05
Discharged with good neurologic outcome, n (%)	51 (29.1)	16 (19.8)	35 (37.2)	<0.05
Length of survival after discharge, n (%)				
<1 month	2 (1.1)	1 (1.2)	1 (1.1)	0.56
1 to 6 months	2 (1.1)	0 (0)	2 (2.1)	
6 month to 1 year	1 (0.6)	0 (0)	1 (1.1)	
>1 year	33 (18.9)	14 (17.3)	19 (20.2)	

	Overall (n=175)	TTM (n=81)	Non-TTM (n=94)	<i>p</i>
Unknown	137 (78.3)	66 (81.5)	71 (75.5)	

*
out of 118 total deaths (61 TTM deaths, 57 non-TTM deaths)