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Prognostic value of targeted temperature management on outcomes of hanging-induced out-of-hospital cardiac arrest
A nationwide observational study

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Abstract

This study aimed to evaluate the prognostic significance of targeted temperature management (TTM) on hanging-induced out-of-hospital cardiac arrest (OHCA) patients using nationwide data of South Korea.

Adult hanging-induced OHCA patients from 2008 to 2018 were included in this nationwide observational study. Patients who assigned into 2 groups based on whether they did (TTM group) or did not (non-TTM group) receive TTM. Outcome measures included survival to hospital discharge and a good neurological outcome at hospital discharge.

Among the 293,852 OHCA patients, 3545 patients (non-TTM, n = 2762; TTM, n = 783) were investigated. After propensity score matching for all patients, 783 matched pairs were available for analysis. We observed no significant inter-group differences in the survival to hospital discharge (non-TTM, n = 27 [3.4%] vs TTM, n = 23 [2.9%], $P = .666$) or good neurological outcomes (non-TTM, n = 23 [2.9%] vs TTM, n = 14 [1.8%], $P = .183$). In the multivariate analysis, prehospital return of spontaneous circulation (odds ratio [OR], 22.849; 95% confidence interval [CI], 11.479–45.481, $P < .001$) was associated with an increase in survival to hospital discharge, and age (OR, 0.971; 95% CI, 0.944–0.998, $P = .035$), heart disease (OR, 16.875; 95% CI, 3.028–94.036, $P = .001$), and prehospital return of spontaneous circulation (OR, 133.251; 95% CI, 30.512–581.930, $P < .001$) were significant prognostic factors of good neurological outcome. However, TTM showed no significant association with either outcome.

There were no significant differences in the survival to hospital discharge and good neurological outcomes between non-TTM and TTM groups of hanging-induced OHCA patients.

Abbreviations: AOR = adjusted odds ratio, CC = conventional cooling, CD = cooling devices, CI = confidence interval, CPC = cerebral performance categories, CPR = cardiopulmonary resuscitation, EMS = emergency medical service, KCDC = Korean Centres for Disease Control and Prevention, OHCA = out-of-hospital cardiac arrest, OHCAS = Out-of-Hospital Cardiac Arrest Surveillance, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

Keywords: hanging, observational study, out-of-hospital cardiac arrest, prognosis, survival, targeted temperature management

1. Introduction

Hanging is a common suicide method in many countries, including South Korea, Japan, and Australia.[1–3] Although restricting access to potentially lethal means has reduced deaths from some suicidal methods, such as firearms and pesticide poisoning,[4] the number of suicides from hanging has increased in recent years in some regions.[5–7] Given the significant mortality of suicidal hanging,[1–2] these staggering statistics

highlight a significant public health problem. Suicide from hanging is characterized by cerebral hypoxia and neuronal cell death secondary to asphyxiation.[8] When hanging results in out-of-hospital cardiac arrest (OHCA), survival rates of patients are lower than 30%.[9] As most cardiac arrests consequent to suicidal hanging are unwitnessed, the outcome of these victims is generally dismal.[1,3] There is no specific treatment available for patients with hanging-induced cardiac arrest.[9,10] Targeted temperature management (TTM) is widely recommended and implemented critical care treatment for postcardiac arrest patients with comatose mental status.[11,12]

TTM minimizes neuronal damage of the brain and improves outcomes in postresuscitation care.[13] The potential mechanisms of TTM include lowering the cerebral metabolic rate for oxygen, suppression of the chemical reaction related to reperfusion injury, and activation of antiapoptotic mechanisms.[14,15] However, its effect on hanging-induced OHCA has been relatively unexplored. There are some case reports[16,17] and relatively small-scale retrospective studies[3,18–23] that examine the effect of TTM on the outcome of hanging-induced OHCA. However, these show controversial results or include small a sample to detect statistically significant outcomes. Therefore, we planned to evaluate the prognostic significance of TTM on hanging-induced OHCA patients using nationwide data of South Korea. This study aimed to assess the relationship between TTM, survival to discharge, and neurological outcome for hanging-induced OHCA patients.

2. Methods

2.1. Study design and settings

This was a retrospective observational study using nationwide data from the Out-of-Hospital Cardiac Arrest Surveillance (OHCAS) of the Korean Centres for Disease Control and Prevention (KCDC) from January 2008 to December 2018.

OHCAS was conducted in 17 provinces of South Korea with approximately 50 million participants and included various data of cardiac arrest patients from prehospital stage to hospital stage. The local ethics committee approved this study in 2020 (Kangnam Sacred Heart Hospital Institutional Review Board; IRB No. 2020-07-005) and informed consent was waived because of the retrospective nature of the study and the use of anonymous clinical data for the analysis. The KCDC approved the use of the data for this study in 2020. The methodology of this study was consistent with the Strengthening the Reporting of Observational Studies in Epidemiology checklist for observational studies.

2.2. Data source

The OHCAS is a population-based, emergency medical service (EMS)-assessed OHCA registry and retrospective patient cohort. The information on OHCA patients was obtained from the EMS records entered by EMS providers immediately after the transport of OHCA patients, and the data of OHCA patients for hospital care and outcomes at hospital discharge was provided by the KCDC. Medical record reviewers of KCDC visited all emergency departments and hospitals to where the OHCA patients were transported and reviewed the medical records.

The OHCAS contains information that describes basic characteristics of patients and settings, EMSs, emergency departments care, hospital procedures, and the outcomes at discharge, including mortality and neurological outcomes, using a customized survey form. The registry form was developed based on the Utstein-style guidelines[24] and the Resuscitation Outcome Consortium Project.[25]

2.3. Study population

From January 2008 to December 2018, a total of 293,852 OHCA patients were registered in the OHCAS. Among them, adult OHCA patients (older than 18 years) who had hanging as the cause of cardiac arrest and sustained (more than 20 minutes) return of spontaneous circulation (ROSC) were included in the study. The comatose mental status of patients was defined as a lack of meaningful response to verbal commands. OHCA patients were excluded from the study if they experienced other causes of cardiac arrest than hanging, were younger than 18 years of age, and/or there was invalid data on neurological status or survival and missing information on TTM methods. Patients who had received TTM were assigned to the TTM group, whereas those who had not received TTM were assigned to the non-TTM group. Hanging is defined as the case of airway closure caused by hanging from the neck, wherein there are traces of rope around the neck or the neck is found to be in a hanging condition. When a case was of a person being strangled by another, the case was excluded from the study population.

2.4. Variables

Information on demographic factors (age, sex), underlying disease of patients (hypertension, diabetes mellitus, heart disease, chronic kidney disease, stroke, dyslipidemia), geographical factors of the OHCA (metropolitan city vs nonmetropolitan city), places of cardiopulmonary resuscitation (CPR) (public places vs nonpublic places), bystander CPR, initial monitored rhythm (shockable vs nonshockable), reperfusion therapy (intravenous thrombolysis and percutaneous coronary intervention), mechanical CPR, extracorporeal membrane oxygenation, and cooling method of TTM were collected.

The underlying disease of patients was the disease diagnosed by the doctor before cardiac arrest and clearly stated in the medical record. Definition and detailed classification of underlying disease is described in Supplementary Data (see Table S1, Supplemental Digital Content, http://links.lww.com/MD2/A868, which illustrates the definition and classification of underlying disease). Public places were defined as places generally open and near to people such as roads, public buildings, parks, and beaches. Detailed classification of cardiac arrest sites is summarized in supplementary data (see Table S2, Supplemental Digital Content, http://links.lww.com/MD2/A869, which illustrates the classification of cardiac arrest sites). A shockable rhythm was defined as ventricular fibrillation and pulseless ventricular tachycardia. Sustained ROSC was defined for all rhythms as conversion to the spontaneous rhythm that was sustained for more than 20 minutes. Information on mechanical CPR, reperfusion therapy such as intravenous thrombolysis or percutaneous coronary intervention, and application of extracorporeal membrane oxygenation were also obtained from the medical records.

The application and type of TTM methods were determined by the physicians and hospital protocol. Cooling methods of TTM were applied as conventional cooling (CC) or cooling devices (CD). CCs were defined as basic external CD that included fans

and ice packs. CDs were defined as any surface or intravascular CD that have temperature feedback control mechanism such as Arctic Sun (Medivance Corp, Louisville, KY), Gaymar (Gaymar Industries, Orchard Park, NY), Blanketrol III (Cincinnati Sub-Zero Products, Cincinnati, OH), Emcools Flex.Pad (Emcools, Vienna, Austria), and CoolGard 3000 Thermal Regulation System (Alsius Corporation, Irvine, CA). All TTM protocol in South Korea adheres to the international 2010 to 2015 American Heart Association guidelines (target temperature: 32–36℃, maintenance time: 12–24 hours).[26,27]

2.5. Outcome measures

The primary outcome was survival to hospital discharge and good neurological outcome at hospital discharge, assessed using the Glasgow–Pittsburgh Cerebral Performance Categories (CPC) scale. CPC 1 and 2 were classified as good neurological status. CPC 3, 4, and 5 were classified as poor neurological status.

2.6. Statistical analysis

Categorical variables were expressed as frequencies and percentages and continuous variables were expressed as medians and interquartile range or means and standard deviations. The normality of each continuous variable was assessed using the Kolmogorov–Smirnov test. Non-normally distributed data are presented as medians with interquartile ranges.

The independent sample t-test for parametric data or Mann–Whitney U test for nonparametric data was used for continuous variables and Pearson chi-square test or Fisher exact test was used for categorical variables.

To minimize the impact of potential confounders and selection bias, propensity score matching was used to compensate for the differences in baseline patient characteristics between the 2 groups of patients. We performed 1:1 propensity score matching (nearest neighbor) to select the participants in both the non-TTM and TTM groups. After estimating the propensity scores, we performed a multivariate logistic regression analysis to determine the prognostic factors influencing survival to hospital discharge and good neurological outcomes of hanging-induced OHCA patients and we also used multivariate logistic regression to analyze the effect of TTM on the outcome of hanging-induced cardiac arrest patients according to the cooling methods of TTM. The factor was calculated as the adjusted odds ratio (AOR) with 95% confidence intervals (CI). To investigate the effect of 2 prognostic factors (witnessed cardiac arrest and prehospital ROSC) on the efficacy of TTM in hanging-induced cardiac arrest patients, we performed further subgroup analysis for patients with witnessed cardiac arrest and prehospital ROSC, respectively.

The model of multivariate logistic regression was stepwise backward elimination. Any variables with $P < .05$ in univariate analyses were included in the multivariate regression analysis. All statistical analysis was conducted by SPSS version 20.0 software (IBM, Armonk, NY) and R package (R version 3.3.2), and $P < .05$ was considered statistically significant.

3. Results

3.1. Characteristics of study patients

Of the 293,852 OHCA patients who were registered during the study period, 290,064 patients were primarily excluded for the

following reasons: non-hanging cause of cardiac arrest (n = 279,176), younger than 18 years of age (n = 308), Do-not-resuscitate or dead-on-arrival (n = 7335), nonsustained ROSC (n = 3245). Further, 243 patients with invalid data for CPC score or survival were secondarily excluded. The remaining 3545 adult hanging-induced OHCA patients were finally enrolled in this study. Of these, 2762 patients were included in the non-TTM group and 783 in the TTM group (Fig. 1).

Baseline characteristics of the non-TTM and TTM groups before propensity score matching are summarized in Table 1. There were significant differences between the 2 groups in terms of sex (male vs female; 1585 [57.4%] vs 407 [52.0%], $P = .008$), age (49 [37–61] vs 45 [34–56], $P < .001$), geographical factor (metropolitan city vs nonmetropolitan city; 1236 [44.8%] vs 452 [57.7%], $P < .001$), bystander CPR (received vs not received; 497 [18.0%] vs 269 [34.4%], $P < .001$), prehospital ROSC (259 [9.4%] vs 127 [16.2%], $P < .001$), and mechanical CPR (received vs not received; 98 [3.5%] vs 269 [6.1%], $P = .002$).

3.2. Characteristics of patients matched for propensity scores

After propensity score matching was performed for all patients, 783 matched pairs of patients were available for analysis. There were no significant differences for all variables among the matched patients between the 2 groups (Table 2).

3.3. Outcomes for propensity-matched patients

In the outcome analysis, we observed no significant difference in the survival to hospital discharge (27 [3.4%] vs 23 [2.9%], $P = .666$) and good neurological outcomes (23 [2.9%] vs 14 [1.8%], $P = .183$) between the non-TTM and TTM groups.

3.4. Multivariate logistic analysis for outcomes at hospital discharge

The prognostic factor for survival to hospital discharge in propensity-matched patients: after multivariate logistic regression analysis, 1 variable was significantly associated with hospital survival.

Prehospital ROSC (odds ratio, 22.849; 95% CI, 11.479–45.481, $P < .001$) was associated with survival to hospital discharge. However, the TTM did not influence the survival to hospital discharge (Table 3).

Prognostic factors for good neurological outcome in propensity-matched patients: After multivariate logistic regression analysis, age (AOR, 0.971; 95% CI, 0.944–0.998, $P = .035$), heart disease (AOR, 16.875; 95% CI, 3.028–94.036, $P = .001$), and prehospital ROSC (AOR, 133.25; 95% CI, 30.512–581.930, $P < .001$), were associated with good neurological outcome. However, The TTM did not influence the neurological outcome at hospital discharge (Table 3).

3.5. Multivariate logistic analysis for outcomes at hospital discharge as per cooling methods

None of cooling methods received by the TTM group were associated with an increased likelihood of achieving survival to hospital discharge (exclusively CC: AOR, 0.538; 95% CI, 0.0165–1.749, $P = .302$; CD + CC: 0.950 [0.450–2.004], $P = .892$; exclusively CD: 0.157 [0.020–1.224], $P = .077$; and
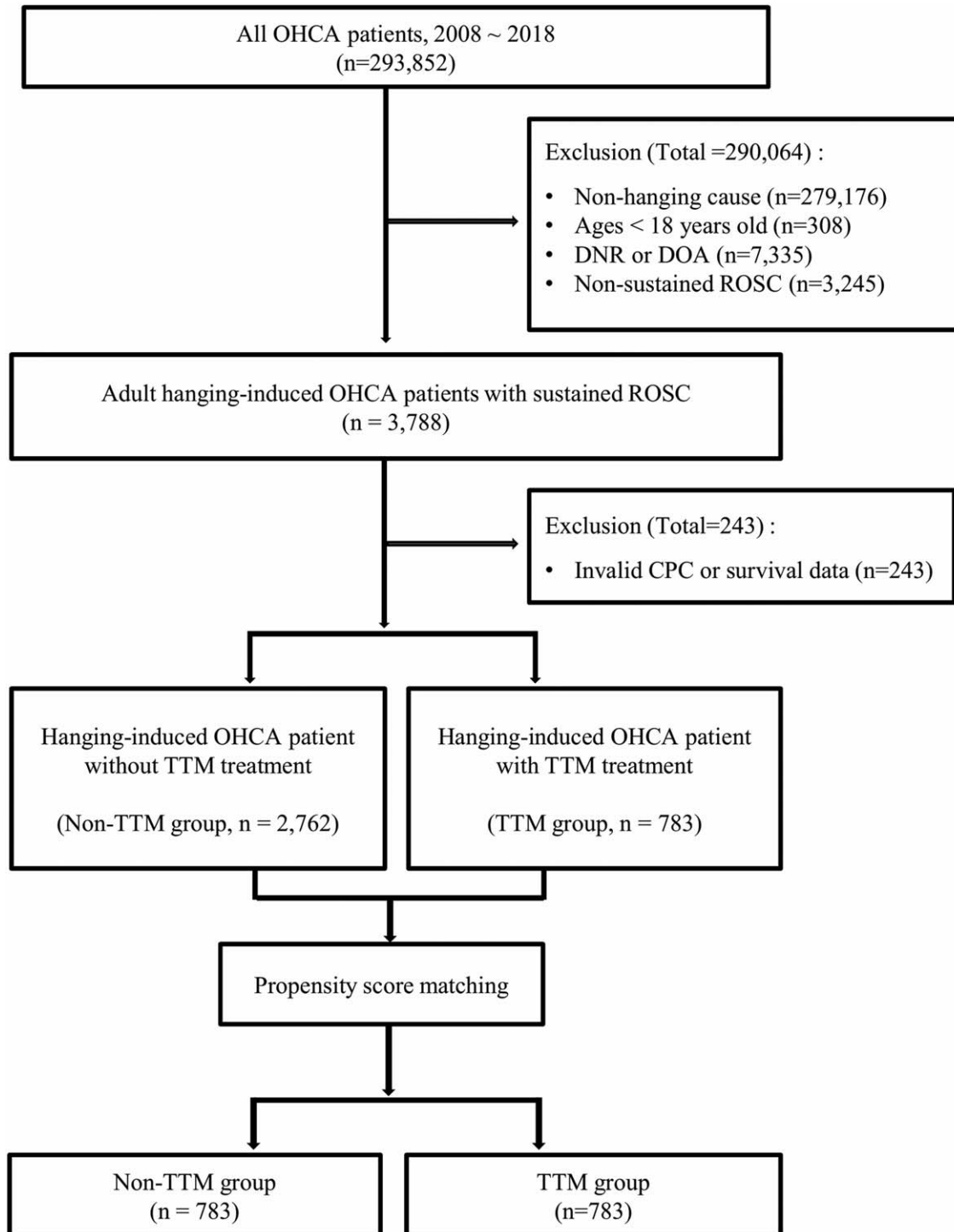
Figure 1. Flow diagram of the study population. Sustained ROSC was defined as sustained circulation that lasted more than 20 min. CPC = cerebral performance category, DNR = do-not-resuscitate, DOA = dead-on-arrival, OHCA = out-of-hospital cardiac arrest, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

unknown methods: 1.279 [0.438–3.734], P = .652) and good neurological outcome at hospital discharge (exclusively CC: AOR [95% CI], 0.361 [0.068–1.907], P = .230; CD + CC: 0.403 [0.145–1.123], P = .082; exclusively CD: 0.166 [0.021–1.341], P = .092; and unknown methods: 1.398 [0.449–4.355], P = .564) compared to those received by the non-TTM group (Table 4).

3.6. Subgroup analysis for patients with witnessed hanging-induced cardiac arrest and patients with prehospital ROSC for survival to hospital discharge and good neurological outcomes

Baseline characteristics of patients with witnessed cardiac arrest and patients with prehospital ROSC between the non-TTM and

Table 1

Baseline characteristics of patients according to non-TTM or TTM.

Variables	Total (N = 3545)	Non-TTM (N = 2762)	TTM (N = 783)	*P* value
Sex				.008
Male	1992 (56.2%)	1585 (57.4%)	407 (52.0%)	
Female	1553 (43.8%)	1177 (42.6%)	376 (48.0%)	
Age, yr	48[37–60]	49 [38–61]	45 [34–56]	<.001
Underlying disease				
HTN	492 (13.9%)	388 (14.0%)	104 (13.3%)	.625
DM	314 (8.9%)	254 (9.2%)	60 (7.7%)	.207
Heart disease	93 (2.6%)	68 (2.5%)	25 (3.2%)	.316
Chronic kidney disease	20 (0.4%)	16 (0.6%)	4 (0.5%)	1.000
Respiratory disease	53 (1.5%)	43 (1.6%)	10 (1.3%)	.687
Stroke	89 (2.5%)	76 (2.8%)	13 (1.7%)	.111
Dyslipidemia	52 (1.5%)	43 (1.6%)	9 (1.1%)	.504
Metropolitan city	1688 (47.6%)	1236 (44.8%)	452 (57.7%)	<.001
Public place of CA	243 (6.9%)	194 (7.0%)	49 (6.3%)	.504
Witnessed CA	105 (3.0%)	71 (2.6%)	34 (4.3%)	.014
Bystander CPR	766 (21.6%)	497 (18.0%)	269 (34.4%)	<0.001
Initial shockable rhythm	23 (0.6%)	17 (0.6%)	6 (0.8%)	.832
Prehospital ROSC	386 (10.9%)	259 (9.4%)	127 (16.2%)	<.001
Reperfusion treatment[*]	7 (0.2%)	4 (0.1%)	3 (0.4%)	.186
Mechanical CPR	146 (4.1%)	98 (3.5%)	48 (6.1%)	.002
ECMO	6 (0.2%)	3 (0.1%)	3 (0.4%)	.184
TTM and cooling methods				
Non-TTM	2762 (77.9%)	2762 (100.0%)	–	
Exclusively CC	190 (5.4%)	–	190 (24.3%)	
CC + CD	346 (9.8%)	–	346 (44.2%)	
Exclusively CD	150 (4.2%)	–	150 (19.2%)	
Unknown methods	97 (2.7%)	–	97 (12.4%)	
Outcomes at hospital discharge				
Survival	93 (2.6%)	70 (2.5%)	23 (2.9%)	.620
Good neurological outcomes	71 (2.0%)	57 (2.1%)	14 (1.8%)	.733

CA = cardiac arrest, CC = conventional cooling, CD = cooling devices, CPR = cardiopulmonary resuscitation, DM = diabetes mellitus, ECMO = extracorporeal membrane oxygenation, HTN = hypertension, ROSC = return of spontaneous circulation, TTM = targeted temperature management.
[*] Reperfusion therapy defined as intravenous thrombolysis or percutaneous coronary intervention.

TTM groups before propensity score matching were summarized in Supplementary Data (see Table S3, Supplemental Digital Content, http://links.lww.com/MD2/A870 and Table S4, Supplemental Digital Content, http://links.lww.com/MD2/A871, which illustrates the baseline characteristics of patients with witnessed hanging-induced cardiac arrest and patients with prehospital ROSC, respectively).

3.7. Outcomes for witnessed cardiac arrest patients after propensity score matching

In the outcome analysis, we observed no significant difference in the survival to hospital discharge (2 [2.9%] vs 2 [5.8%], *P* = .493) and good neurological outcomes (1 [2.9%] vs 1 [2.9%], *P* = .493) between the non-TTM and TTM groups (see Table S5, Supplemental Digital Content, http://links.lww.com/MD2/A872, which illustrates the baseline characteristics of patients with witnessed hanging-induced cardiac arrest after propensity score matching). In multivariate logistic regression analysis, the TTM did not influence the survival (AOR, 2.192; 95% CI, 0.145–33.097, *P* = .571) and neurological outcome (AOR, 0.886; 95% CI, 0.042–18.554, *P* = .938) at hospital discharge (Table 5).

3.8. Outcomes for patients with prehospital ROSC after propensity score matching

In the outcome analysis, we observed no significant difference in the survival to hospital discharge (26 [20.5%] vs 16 [12.6%], *P* = .128) and good neurological outcomes (19 [15.0%] vs 13 [10.2%], *P* = .073) between the non-TTM and TTM groups (see Table S6, Supplemental Digital Content, http://links.lww.com/MD2/A873, which illustrates the baseline characteristics of patients with prehospital ROSC after propensity score matching). In multivariate logistic regression analysis, The TTM did not influence the survival (AOR, 0.504; 95% CI, 0.250–1.017, *P* = .056) and neurological outcome (AOR, 0.518; 95% CI, 0.230–1.169, *P* = .113) at hospital discharge (Table 6).

4. Discussion

We compared the TTM group with the non-TTM group in terms of survival to hospital discharge and good neurological outcomes from among hanging-induced OHCA patients with sustained ROSC. Our nationwide, retrospective, observational, multicenter study indicated that the patients who received TTM had no better survival and neurologic outcome than those who did not receive it.

Table 2

Baseline characteristics of patients after propensity score matching.

Variables	Total (N = 1566)	Non-TTM (N = 783)	TTM (N = 783)	P value
Sex				1.000
Male	813 (51.9%)	406 (51.9%)	407 (52.0%)	
Female	753 (48.1%)	377 (48.1%)	376 (48.0%)	
Age, yr	44 [34–55]	43 [33–54]	45 [34–56]	.193
Underlying disease				
HTN	203 (13.0%)	99 (12.6%)	104 (13.3%)	.763
DM	108 (6.9%)	48 (6.1%)	60 (7.7%)	.273
Heart disease	44 (2.8%)	19 (2.4%)	25 (3.2%)	.445
Chronic kidney disease	9 (0.6%)	5 (0.6%)	4 (0.5%)	1.000
Respiratory disease	18 (1.1%)	8 (1.0%)	10 (1.3%)	.813
Stroke	25 (1.6%)	12 (1.5%)	13 (1.7%)	1.000
Dyslipidemia	1550 (99.0%)	776 (99.1%)	774 (98.9%)	.802
Metropolitan city	901 (57.5%)	449 (57.3%)	452 (57.7%)	.919
Public place of CA	91 (5.8%)	42 (5.4%)	49 (6.3%)	.517
Witnessed CA	61 (3.9%)	27 (3.4%)	34 (4.3%)	.433
Bystander CPR	546 (34.9%)	277 (35.4%)	269 (34.4%)	.710
Initial shockable rhythm	10 (0.6%)	4 (0.5%)	6 (0.8%)	.751
Prehospital ROSC	244 (15.6%)	117 (14.9%)	127 (16.2%)	.531
Reperfusion treatment	4 (0.3%)	1 (0.1%)	3 (0.4%)	.625
Mechanical CPR	89 (5.7%)	41 (5.2%)	48 (6.1%)	.513
ECMO	5 (0.3%)	2 (0.3%)	3 (0.4%)	1.000
TTM - cooling methods				
Non-TTM	783 (50.0%)	783 (100.0%)	–	
Exclusively CC	190 (12.1%)	–	190 (24.3%)	
CC + CD	346 (22.1%)	–	346 (44.2%)	
Exclusively CD	150 (9.6%)	–	150 (19.2%)	
Unknown methods	97 (6.2%)	–	97 (12.4%)	
Outcomes at hospital discharge				
Survival	50 (3.2%)	27 (3.4%)	23 (2.9%)	.666
Good neurological outcomes	37 (2.4%)	23 (2.9%)	14 (1.8%)	.183

Reperfusion therapy defined as intravenous thrombolysis or percutaneous coronary intervention.

CA = cardiac arrest, CC = conventional cooling, CD = cooling devices, CPR = cardiopulmonary resuscitation, DM = diabetes mellitus, ECMO = extracorporeal membrane oxygenation, HTN = hypertension, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

Hanging is 1 of the main causes of suicide and its' incidence is increasing over time in the United States.[28] A recent survey from Japan reported that hanging increased by 60% during the last 37 years (from 1979 to 2016) and remained the primary method of suicide.[29] In a group of hanging-related OHCA, the survival rate from France was 2.1% and 4.2% in Osaka respectively.[30,31]

Table 3

Multivariable logistic regression analysis for outcomes at hospital discharge in propensity-matched patients.

	AOR (95% CI)	P value
Survival to hospital discharge		
Prehospital ROSC	22.849 (11.479–45.481)	<.001
Reperfusion therapy	13.080 (0.728–234.982)	.081
TTM	0.735 (0.397–1.361)	.328
Good neurologic outcome		
Age	0.971 (0.944–0.998)	.035
Heart disease	16.875 (3.028–94.036)	.001
Prehospital ROSC	133.251 (30.512–581.930)	<.001
TTM	0.480 (0.227–1.017)	.055

Model of multivariate logistic regression analysis is stepwise backward elimination.

AOR = adjusted odds ratio, CI = confidence interval, N/A = not available, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

Table 4

Multivariable logistic regression analysis for outcomes at hospital discharge as per cooling methods in propensity-matched patients.

	AOR (95% CI)	P value
Survival to hospital discharge[*]		
TTM and cooling methods		
Non-TTM	1.000	
Exclusively CC	0.538 (0.0165–1.749)	.302
CD + CC	0.950 (0.450–2.004)	.892
Exclusively CD	0.157 (0.020–1.224)	.077
Unknown methods	1.279 (0.438–3.734)	.652
Good neurologic outcome[*]		
TTM and cooling methods		
Non-TTM	1.000	
Exclusively CC	0.361 (0.068–1.907)	.230
CD + CC	0.403 (0.145–1.123)	.082
Exclusively CD	0.166 (0.021–1.341)	.092
Unknown methods	1.398 (0.449–4.355)	.564

Model of multivariate logistic regression analysis is stepwise backward elimination.

AOR = adjusted odds ratio, CC = conventional cooling, CD = cooling devices, CI = confidence interval, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

[*] Adjusted odds ratio for sex, age, underlying disease, metropolitan city, places of cardiac arrest, witnessed cardiac arrest, bystander cardiopulmonary resuscitation, prehospital return of spontaneous circulation, reperfusion treatment, mechanical cardiopulmonary resuscitation, and extracorporeal membrane oxygenation.

Table 5

Multivariable logistic regression analysis for outcomes of witnessed hanging-induced cardiac arrest patients after propensity score matching.

	AOR (95% CI)	P value
Survival to hospital discharge		
Prehospital ROSC	8.833 (0.739–105.575)	.085
TTM	2.192 (0.145–33.097)	.571
Good neurologic outcome		
Prehospital ROSC	6.074 (0.155–237.800)	.335
TTM	0.886 (0.042–18.554)	.938

The model of multivariate logistic regression analysis is stepwise backward elimination.
AOR = adjusted odds ratio, CI = confidence interval, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

The significant morbidity and mortality of hanging can be explained by its mechanism of injury. The compression of neck soft tissues results in jugular venous obstruction, stagnant hypoxia, cerebral edema, and loss of consciousness.[32,33] The loss of muscular tone further tightens the ligature around the neck, resulting in carotid arterial obstruction, cerebral hypoxia, airway obstruction, and death.[3,34]

The 2015 American heart association guidelines recommended that comatose adult patients with ROSC post-CA receive TTM.[35] TTM decreases the harmful effects of ischemia by reducing a body's need for oxygen and also contributes to limiting reperfusion injury due to oxidative stress when blood supply to the tissue is restored.[36] The presence of cardiac arrest is associated with higher severity of the injury and worse survival and functional outcome.

The survival rate of cardiac arrest caused by hanging was significantly lower than presumed cardiac arrest (3.3% vs 12%) in a retrospective study of the past 10 years.[37] Our study demonstrated an overall survival of 2.9% (n = 23) and a good neurological outcome of 1.8% (n = 14) from the TTM group. A possible explanation for this could be that several factors known to improve outcomes were much less prevalent among hanging-induced OHCA patients as they had lower proportions of witnessed arrests, bystander CPR, and shockable rhythm.

In our study, there were few rates of witnessed arrests (3.9%) and shockable rhythm (0.6%), which indicate that the real hypoxia time in hanging-induced cardiac arrests could be significantly longer than that in cardiac arrests with other

Table 6

Multivariable logistic regression analysis for outcomes of hanging-induced cardiac arrest patients with prehospital ROSC after propensity score matching.

	AOR (95% CI)	P value
Survival to hospital discharge		
Age	0.971 (0.946–0.996)	.022
Heart disease	10.676 (1.863–61.168)	.008
TTM	0.504 (0.250–1.017)	.056
Good neurologic outcome		
Age	0.960 (0.931–0.990)	.009
Heart disease	16.488 (2.571–105.729)	.003
TTM	0.518 (0.230–1.169)	.113

The model of multivariate logistic regression analysis is stepwise backward elimination.
AOR = adjusted odds ratio, CI = confidence interval, ROSC = return of spontaneous circulation, TTM = targeted temperature management.

medical-cause origins. Therefore, the cardiac arrest patients in our study could already have a high degree of brain damage before hospital arrival.

In the multivariate logistic analysis for outcomes, TTM showed no significant difference in in-hospital survival and neurological outcome between the 2 groups (TTM vs non-TTM). These results indicate that the neuroprotective effect of TTM was minimal for hanging-induced OHCA patients. And main cause could be postulated the high degree of brain damage they sustained before TTM.

Even though brain imaging data such as computed tomography and magnetic resonance imaging was not evaluated in this study, hanging-induced OHCA patients may have had a more severe hypoxic brain injury than patients with other medical causes of cardiac arrest that result in hypoxic brain damage because the brain hypoxia in the former is unlike that seen in the latter.[20] In cases of hanging, there could be other causes of cardiac arrest than hypoxia. Cervical vessel occlusion, spinal cord injury, carotid sinus stimulation, and an increase in vagal tone may occur and could cause an arrest in hanging patients.[19] These features of hanging-induced OHCA maybe weaken the neuroprotective effect of TTM.

Our multivariate analysis also suggested that prehospital ROSC was a significant factor associated with survival to hospital discharge and good neurological outcome. The prolonged duration of CPR causes a lower blood supply to the brain than normal, leading to additional cerebral damage and a low probability of ROSC.[38] Hence, prehospital ROSC could contribute to survival and good neurological outcomes of hanging-induced OHCA patients by decreasing additional brain damage.

Other factors that could impact outcomes are the cooling methods of TTM, such as CC and CD. These cooling techniques can be used simultaneously or separately to reach the target temperature of TTM quickly. The 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care states that temperature control is best achieved using devices that have a continuous temperature feedback control mechanism.[39] Although CC is easy-to-use and more available than CD, they can result in unpredictable variations in body temperature than CD due to lack of temperature feedback control mechanism.[13,40–43] Therefore, CC methods are known to less effective than CD in minimizing hypoxic brain injury of postcardiac arrest patients.[44,45] However, the relationship between these cooling methods of TTM and clinical outcomes of patients is insignificant in this study. None of only CC, CC + CD, or only CD showed better outcomes compared with patients not treated with TTM. Hence, in patients who have already received severe brain damage like hanging-induced cardiac arrest patients in this study, regardless of the TTM method, TTM might not have much neuroprotective effect, given that TTM itself decreases additional brain damage.

Witnessed cardiac arrest, in addition to prehospital ROSC, has been reported to be a good predictive factor in cardiac arrest patients.[20,45] Thus, we conducted a subgroup analysis for the witnessed cardiac arrest and prehospital ROSC. In all subgroups, however, this investigation found that TTM was not related with improved patient outcomes as compared to non-TTM. Even while prehospital ROSC was a strong predictor of better outcomes, a high proportion of unwitnessed cardiac arrest (95.9%) in individuals with prehospital ROSC could result in

severe hypoxic brain injury.[38] Therefore, TTM may not have a major impact on improving outcomes. In the witnessed hanging-induced cardiac arrest, the number of TTM-treated patients with witnessed cardiac arrests was too small (34 patients) to evaluate the efficacy of TTM, hence a larger sample size is required to determine the exact effect of TTM on the outcome.

4.1. Limitations

This study has several limitations. First, the retrospective observational nature of the study renders it to potential biases, including selection bias and reporting bias. Although we used propensity score matching, there was still a risk of bias. Therefore, the results should be cautiously interpreted. Second, we could not assess long-term survival and neurological outcome after hospital discharge. The measured outcomes at hospital discharge could have changed after hospital discharge.[46] Therefore, the survival and neurological outcomes of hanging-induced OHCA patients could be different if the outcomes were followed up and measured after hospital discharge. Third, we did not evaluate potential confounders such as hemodynamic status, laboratory findings, and exact mental status before TTM treatment because related information was not provided in the registry. These factors could affect the outcomes of patients in addition to the TTM treatment. Therefore, the results of this study should be confirmed through well-designed studies that include additional variables related to the patient's status. Fourth, the generalization of this study is uncertain. The study was performed based on the data of the South Korea EMS system. The variables of the data may differ from those of other countries that have different EMS and medical systems. For more generalizable results, further data from other races or countries are required.

5. Conclusions

In the overall-matched patients of hanging-induced OHCA, receiving TTM may have no significant effect on increasing survival to hospital discharge and good neurological outcomes. Nevertheless, these results should be cautiously interpreted considering the possible bias. Further studies are also needed to confirm the results by measuring long-term outcomes and including more detailed in-hospital data of patients.

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