Hypothermia as an Outcome Predictor Tool in Pediatric Trauma
A Propensity-Matched Analysis

Thomas R. McCarty, MD, Thomas J. Abramo, MD,* Robert T. Maxson, MD,† Gregory Albert, MD,‡ Mallikarjuna R. Rettiganti, PhD,§ Marie E. Saylors, MPH,§ Jonathan W. Orsborn, MD,|| and Amanda I. Hollingsworth, MD¶*

Objective: Hypothermia is an independent risk factor for mortality in adult trauma patients. Two small studies have shown similar results in pediatric trauma patients. Temperature is not included in any pediatric trauma assessment scores. This study sought to compare mortality and various descriptive outcomes between pediatric hypothermic and normothermic trauma patients.

Methods: Data were obtained from the National Trauma Database from 2009 to 2012. Patients meeting inclusion criteria were stratified by presence of isolated head injury, head injury with multiple trauma, and absence of head injury. These groups were then subdivided into hypothermic (temperature ≤36°C) and normothermic groups. We used propensity score matching to 1:1 match hypothermic and normothermic patients. Mortality, neurosurgical interventions, endotracheal intubation, blood transfusion, length of stay, laparotomy, thoracotomy, conversion of cardiac rhythm, and time receiving mechanical ventilation were evaluated.

Results: Data from 3,011,482 patients were obtained. There were 414,562 patients who met the inclusion criteria. In all patients meeting inclusion criteria, hypothermia was a significant risk factor in all outcomes measured. Following stratification and 1:1 matching, in all groups, hypothermia was associated with increased mortality ($P < 0.0001$), increased rate of endotracheal intubation ($P < 0.0002$), increased need for blood transfusion ($P < 0.0025$), and conversion of cardiac rhythm ($P < 0.0027$).

Conclusion: Hypothermia has been shown to be a significant prognostic indicator in the pediatric trauma patient with further potential application. Future studies are indicated to evaluate the incorporation of hypothermia into the Pediatric Trauma Score not only to help predict injury severity and mortality but also to improve appropriate and expeditious patient transfer to pediatric trauma centers and potentially facilitate earlier intervention.

Key Words: hypothermia, mortality, pediatric trauma, trauma scoring systems

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Trauma remains the leading cause of pediatric death and disability in the United States.[1,2] More than 10 million children will present to US emergency departments for treatment of an injury each year, and more than 10,000 children in the United States die of serious trauma each year.[1,3] Although advances have been made in pediatric trauma research, much of what is known and taught regarding pediatric trauma triage, evaluation, and management is extrapolated from adult trauma clinical experience and research.

Several tools and classification scoring systems have been developed in an attempt to quantify the severity of trauma and associated morbidity and mortality.[4] Most of these systems were devised with respect to adult trauma patients. Eventually, the Pediatric Trauma Score (PTS) was designed to help predict injury severity and mortality of the pediatric trauma patient.[5,6] However, because of inconsistency in scoring across different trauma populations and pediatric age groups, there is a relative lack of consensus as to which scoring system is best.[4,7,8] Temperature is not included in the PTS.

Hypothermia has been well identified as an independent risk factor for mortality in adult trauma patients.[9–13] However, only a few single-site pediatric studies have shown hypothermia to be associated with increased mortality in trauma patients.[14,15] To our knowledge, there has not been a large, multicenter investigation into how hypothermia predicts morbidity and mortality in pediatric trauma. This study sought to compare mortality and other descriptive outcomes between hypothermic and normothermic pediatric trauma patients.

METHODS

We conducted a retrospective review of the National Trauma Data Bank (NTDB), managed by the American College of Surgeons (ACS), between the years 2009 and 2012.[16,17] The University of Arkansas for Medical Sciences Institutional Review Board approved this study. All records entered into the NTDB from 2009 to 2012 were queried and evaluated for potential inclusion. Exclusion criteria included those with age missing or older than 18 years, temperature missing or greater than 38°C, burn injuries, submersion injuries, or injuries listed as other/unspecified. Hypothermia was defined per Advanced Trauma Life Support guidelines as temperature 36°C or less.[1]

Those meeting inclusion criteria were stratified by the presence of isolated head injury, head injury with multiple system trauma, and absence of head injury. Head injury was identified by the *International Classification of Diseases, Ninth Revision* (*ICD-9*) code or Abbreviated Injury Scale of greater than 1 (see Table, Supplemental Digital Content 1, which shows list of head injuries and corresponding *ICD-9* codes, http://links.lww.com/PEC/A294).[18] These groups were then subdivided into hypothermic and normothermic groups. To control for the nonrandom assignment of patients to the groups, we constructed a logistic regression model that predicted the likelihood of hypothermia (the propensity score). Covariates in the model included demographics, type of injury, intent, mechanism, mode of transport,

From the *Section of Emergency Medicine, Department of Pediatrics, †Section of Pediatric Surgery, Department of Surgery, ‡Section of Pediatric Neurosurgery, Department of Neurosurgery, and §Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, AR; ||Section of Emergency Medicine, Department of Pediatrics, Children's Hospital Colorado, Aurora, CO; and ¶Section of Emergency Medicine, Department of Pediatrics, Arkansas Children's Hospital Northwest, Springdale, AR.

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Reprints: Thomas R. McCarty, MD, Section of Emergency Medicine, Department of Pediatrics, University of Arkansas for Medical Sciences, 1 Children's Way, Slot 512-16, Little Rock, AR 72202 (e-mail: trmccarty06@gmail.com).

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Glasgow Coma Scale (GCS) score, geographic region, ACS trauma verification level, and ACS pediatric trauma verification level. Patients in each group were matched 1:1 using this score. To ensure that the patients were closely matched, we required that the propensity scores for matched pairs be within 0.2 of the pooled SD of the logit of the propensity score.[19] To ensure that the covariates were balanced across comparison groups, we calculated the standard difference.[20] Covariates with standard difference values less than or equal to 10% were considered balanced. All statistical analyses were conducted with SAS version 9.3 (SAS Institute Inc, Cary, NC), using the PSMatching macro.[21]

Mortality, defined as death prior to discharge from the hospital, was the primary outcome measured. Specifically, this study sought to answer whether, after accounting for potential cofounders, hypothermia is associated with increased mortality in pediatric trauma patients. Secondary outcomes include endotracheal intubation, neurosurgical intervention, transfusion of blood components, disposition upon discharge, hospital length of stay (LOS), intensive care unit (ICU) LOS, and time receiving mechanical ventilation. Neurosurgical interventions were identified by procedure codes and defined as craniectomy, craniotomy, cranial decompression, intracranial drainage, intracranial pressure monitoring, ventricular shunt placement, or brain excision (see Table, Supplemental Digital Content 2, which shows procedures and corresponding *ICD-9* codes, http://links.lww.com/PEC/A295).[18] Disposition upon discharge was defined as home or other facility (inpatient rehabilitation, hospice, skilled nursing facility, or other hospital).

Mean and SD were reported for continuous variables; count and percentage were reported for categorical variables. Before matching, the groups were compared using independent *t* tests for continuous variables and χ^2 tests for categorical variables. After matching, the groups were compared using generalized linear models with γ distributions for continuous variables and binary or multinomial distributions for categorical variables.

RESULTS

Data from 3,011,482 patients were extracted from the NTDB between the years 2009 and 2012. A CONSORT (Consolidated Standards of Reporting Trials) diagram is shown in Figure 1. A total of 2,596,920 were excluded: 2,479,416 because of missing age or age older than 18 years; 60,797 because of having no temperature recorded or a temperature greater than 38°C; 19,560 because of burn injury; 450 because of submersion injury; and 36,697 were excluded because the type of injury was other or unspecified (Fig. 1). Initial temperature values were obtained within 30 minutes of arrival in the emergency department. It is unknown if temperatures recorded in the NTDB were core or peripheral body temperatures.

A total of 414,562 patients met the inclusion criteria (see Table, Supplemental Digital Content 3, which shows summary statistics of patients meeting inclusion criteria, http://links.lww.com/PEC/A296). Outcomes were analyzed in patients meeting inclusion criteria prior to stratification and matching (see Table, Supplemental Digital Content 4, which shows outcomes of all patients meeting inclusion criteria, http://links.lww.com/PEC/A297). Among patients meeting inclusion criteria, hypothermia was associated with a significantly higher rate of mortality, endotracheal intubation, neurosurgical intervention, blood transfusion, ICU LOS, hospital LOS, time on ventilator, and discharge to other facility ($P < 0.0001$ for all outcomes). Following stratification, 78,190 patients had isolated head injury, 49,470 patients had head injury with multisystem trauma, and 286,902 patients had no head injury. Summary statistics postmatching for each group are shown in Table 1.

In the isolated head injury group, 16,710 patients were matched 1:1, and outcomes were analyzed (Table 2). Hypothermia was associated with an increased risk of mortality compared with normothermia (4.4% vs 2.7%, $P < 0.0001$). Among patients transferred between facilities, hypothermia was associated with increased mortality (1.2% vs 0.5%, $P = 0.0257$). For patients who

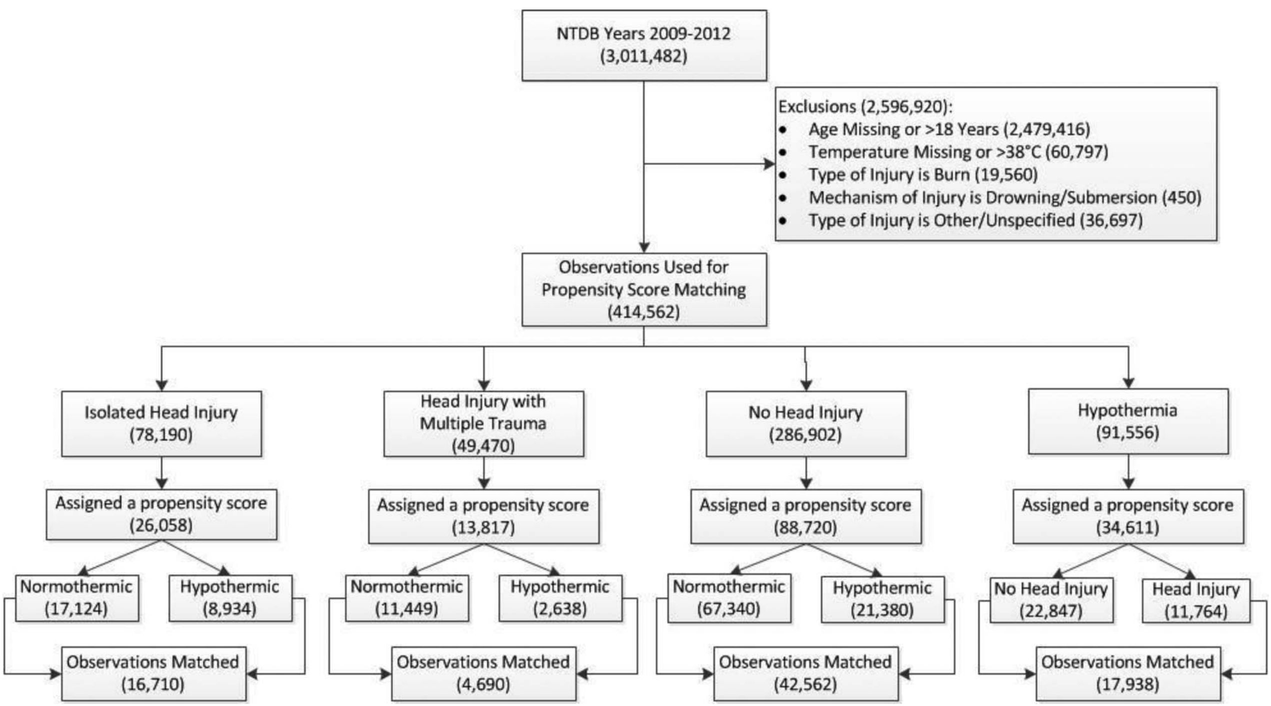

FIGURE 1. CONSORT diagram.

TABLE 1. Summary Statistics in Analysis Groups After Matching

	Isolated Head Injury After Matching			Nonisolated Head Injury After Matching		
	Normothermic	Hypothermic		Normothermic	Hypothermic	
Variables	**(n = 8355)**	**(n = 8355)**	**Std. Diff.**	**(n = 2345)**	**(n = 2345)**	**Std. Diff.**
Age	8.9 (6.6)	8.9 (6.5)	0.0065	10.8 (6.1)	10.9 (6.1)	0.0174
Sex			0.0063			−0.0009
Male	5570 (66.7%)	5545 (66.4%)		1559 (66.5%)	1560 (66.5%)	
Female	2785 (33.3%)	2810 (33.6%)		786 (33.5%)	785 (33.5%)	
Race			0.0315			0.0356
White	5896 (70.6%)	5989 (71.7%)		1527 (65.1%)	1510 (64.4%)	
African American	1004 (12.0%)	995 (11.9%)		353 (15.1%)	370 (15.8%)	
Hispanic or Latino	167 (2.0%)	168 (2.0%)		89 (3.8%)	88 (3.8%)	
Asian	119 (1.4%)	121 (1.5%)		41 (1.8%)	50 (2.1%)	
Other race	1169 (14.0%)	1082 (13.0%)		335 (14.3%)	327 (13.9%)	
Type of injury			0.0016			0.0379
Blunt	8164 (97.7%)	8162 (97.7%)		2314 (98.7%)	2303 (98.2%)	
Penetrating	191 (2.3%)	193 (2.3%)		31 (1.3%)	42 (1.8%)	
Intent			0.0113			0.0438
Assault	467 (5.6%)	462 (5.5%)		78 (3.3%)	89 (3.8%)	
Self-inflicted	45 (0.5%)	52 (0.6%)		6 (0.3%)	11 (0.5%)	
Unintentional	7843 (93.9%)	7841 (93.9%)		2261 (96.4%)	2245 (95.7%)	
Mechanism			0.0259			0.0699
Cut/pierce	23 (0.3%)	22 (0.3%)		2 (0.1%)	4 (0.2%)	
Fall	3447 (41.3%)	3377 (40.4%)		723 (30.8%)	680 (29.0%)	
Firearm	167 (2.0%)	170 (2.0%)		29 (1.2%)	38 (1.6%)	
Motor vehicle	2301 (27.5%)	2354 (28.2%)		1017 (43.4%)	1002 (42.7%)	
Pedal cyclist	406 (4.9%)	410 (4.9%)		111 (4.7%)	111 (4.7%)	
Pedestrian	56 (0.7%)	61 (0.7%)		9 (0.4%)	9 (0.4%)	
Struck by, against	1261 (15.1%)	1232 (14.8%)		282 (12.0%)	306 (13.1%)	
Other	694 (8.3%)	729 (8.7%)		172 (7.3%)	195 (8.3%)	
Mode of transport			0.0289			−0.001
Ground	6574 (78.7%)	6474 (77.5%)		1735 (74.0%)	1736 (74.0%)	
Air	1781 (21.3%)	1881 (22.5%)		610 (26.0%)	609 (26.0%)	
GCS score	13.2 (3.9)	13 (4.0)	−0.042	11.9 (4.8)	11.8 (4.8)	−0.021
ISS	11.6 (8.8)	11.9 (9.5)	0.0297	15.3 (12.4)	15.7 (13.2)	0.038
Region			0.025			0.0469
Midwest	3119 (37.3%)	3023 (36.2%)		732 (31.2%)	710 (30.3%)	
Northeast	694 (8.3%)	697 (8.3%)		648 (27.6%)	621 (26.5%)	
South	2717 (32.5%)	2754 (33.0%)		814 (34.7%)	844 (36.0%)	
West	1825 (21.8%)	1881 (22.5%)		151 (6.4%)	170 (7.3%)	
ACS level			0.0368			0.0437
I	4639 (55.5%)	4687 (56.1%)		1281 (54.6%)	1248 (53.2%)	
II	1334 (16.0%)	1239 (14.8%)		240 (10.2%)	229 (9.8%)	
III	49 (0.6%)	57 (0.7%)		14 (0.6%)	14 (0.6%)	
IV	1 (0.0%)	3 (0.0%)		2 (0.1%)	1 (0.0%)	
Not applicable	2332 (27.9%)	2369 (28.4%)		808 (34.5%)	853 (36.4%)	
ACS pediatric level			0.0138			0.0193
I	4513 (54.0%)	4474 (53.6%)		1166 (49.7%)	1159 (49.4%)	
II	1069 (12.8%)	1106 (13.2%)		206 (8.8%)	219 (9.3%)	
Not applicable	2773 (33.2%)	2775 (33.2%)		973 (41.5%)	967 (41.2%)	

Mean and SD for continuous variables. *P* values prematching calculated using independent *t* tests; *P* values postmatching calculated using paired *t* tests. Count and percentage for categorical variables. *P* values prematching calculated using χ^2 tests; *P* values postmatching calculated using generalized linear models.

ISS, injury severity score.

	No Head Injury After Matching		
	Normothermic	Hypothermic	
Variables	**(n = 21,281)**	**(n = 21,281)**	**Std. Diff.**
Age	10 (5.5)	10 (5.6)	−0.0095
Sex			0.0083
Male	14,317 (67.3%)	14,234 (66.9%)	
Female	6964 (32.7%)	7047 (33.1%)	
Race			0.0398
White	14,883 (69.9%)	14,658 (68.9%)	
African American	2972 (14.0%)	3202 (15.1%)	
Hispanic or Latino	369 (1.7%)	430 (2.0%)	
Asian	322 (1.5%)	341 (1.6%)	
Other race	2735 (12.9%)	2650 (12.5%)	
Type of injury			0.0382
Blunt	19,406 (91.2%)	19,169 (90.1%)	
Penetrating	1875 (8.8%)	2112 (9.9%)	
Intent			0.0279
Assault	1163 (5.5%)	1242 (5.8%)	
Self-inflicted	177 (0.8%)	223 (1.1%)	
Unintentional	19,941 (93.7%)	19,816 (93.1%)	
Mechanism			0.0453
Cut/pierce	996 (4.7%)	1172 (5.5%)	
Fall	9119 (42.9%)	8947 (42.0%)	
Firearm	877 (4.1%)	938 (4.4%)	
Motor vehicle	4860 (22.8%)	4840 (22.7%)	
Pedal cyclist	973 (4.6%)	1002 (4.7%)	
Pedestrian	118 (0.6%)	131 (0.6%)	
Struck by, against	2465 (11.6%)	2477 (11.6%)	
Other	1873 (8.8%)	1774 (8.3%)	
Mode of transport			0.0176
Ground	18,960 (89.1%)	18,842 (88.5%)	
Air	2321 (10.9%)	2439 (11.5%)	
GCS score	15 (1.6)	15 (1.8)	−0.0387
ISS	6 (5.5)	6 (6.4)	0.0171
Region			0.018
Midwest	9751 (45.8%)	9783 (46.0%)	
Northeast	1728 (8.1%)	1742 (8.2%)	
South	5700 (26.8%)	5797 (27.2%)	
West	4102 (19.3%)	3959 (18.6%)	
ACS level			0.0458
I	11,370 (53.4%)	11,166 (52.5%)	
II	3254 (15.3%)	3044 (14.3%)	
III	274 (1.3%)	276 (1.3%)	
IV	15 (0.1%)	12 (0.1%)	
Not applicable	6368 (29.9%)	6783 (31.9%)	
ACS pediatric level			0.0067
I	11,497 (54.0%)	11,568 (54.4%)	
II	2601 (12.2%)	2585 (12.2%)	
Not applicable	7183 (33.8%)	7128 (33.5%)	

TABLE 2. Outcomes in Patients With Head Injury Before and After Propensity Score Matching

	Isolated Head Injury Before Matching				Isolated Head Injury After Matching		
Variables	**Normothermic (n = 55,141)**	**Hypothermic (n = 23,049)**	**Total (n = 78,190)**	***P***	**Normothermic (n = 8355)**	**Hypothermic (n = 8355)**	***P***
Mortality	749 (1.4%)	1207 (5.2%)	1956 (2.5%)	<0.0001	222 (2.7%)	368 (4.4%)	<0.0001
Mortality for transfers	129 (0.2%)	374 (1.6%)	503 (0.6%)	<0.0001	40 (0.5%)	99 (1.2%)	0.0257
Discharge				<0.0001			<0.0001
Home	46,416 (84.2%)	17,508 (76.0%)	63,924 (81.8%)		7148 (85.6%)	6824 (81.7%)	
Other	7929 (14.4%)	4315 (18.7%)	12,244 (15.7%)		977 (11.7%)	1159 (13.9%)	
Length of hospital stay, d	3.3 (5.7)	4.3 (7.6)	3.6 (6.3)	<0.0001	3.9 (6.6)	3.9 (6.4)	0.7439
Length of ICU stay, d	3.4 (5.4)	4.6 (7.0)	3.8 (6.0)	<0.0001	4 (6.0)	4.2 (6.3)	0.0670
Time on ventilator, d	4.9 (6.8)	5.4 (8.6)	5.1 (7.6)	0.0007	5 (6.8)	5.1 (7.7)	0.6758
Neurosurgical intervention	3434 (6.2%)	2179 (9.5%)	5613 (7.2%)	<0.0001	744 (8.9%)	754 (9.0%)	0.7866
Endotracheal tube	2693 (4.9%)	2154 (9.4%)	4847 (6.2%)	<0.0001	539 (6.5%)	647 (7.7%)	0.0017
Exploratory thoracotomy	26 (0.1%)	17 (0.1%)	43 (0.1%)	0.1530	6 (0.1%)	5 (0.1%)	0.7620
Laparotomy	274 (0.5%)	261 (1.1%)	535 (0.7%)	<0.0001	53 (0.6%)	94 (1.1%)	0.0012
Blood transfusion	1231 (2.2%)	1196 (5.2%)	2427 (3.1%)	<0.0001	321 (3.8%)	429 (5.1%)	<0.0001
Conversion of cardiac rhythm	166 (0.3%)	285 (1.2%)	451 (0.6%)	<0.0001	42 (0.5%)	85 (1.0%)	0.0003

Mean and SD for continuous variables. *P* values prematching calculated using independent *t* tests; *P* values postmatching calculated using paired *t* tests. Count and percentage for categorical variables. *P* values prematching calculated using χ^2 tests; *P* values postmatching calculated using generalized linear models.

ISS, injury severity score.

survived, hypothermic patients were more likely to be discharged to another facility compared with normothermic patients (13.9% vs 11.7%, $P < 0.0001$). Hypothermic patients were more likely to require intubation (7.7% vs 6.5%, $P = 0.0017$), undergo blood transfusion (5.1% vs 3.8%, $P < 0.0001$), and undergo conversion of cardiac rhythm (1.0% vs 0.5%, $P = 0.0003$). No significant difference was noted between hospital LOS, ICU LOS, time mechanically ventilated, and frequency of neurosurgical intervention.

In patients with head injury with multisystem trauma, 4690 patients were matched 1:1, and outcomes were analyzed (Table 3). Hypothermia was associated with an increased risk of mortality compared with normothermia (7.5% vs 4.2%, $P < 0.0001$). Patients presenting with hypothermia were more likely to require intubation (10.2% vs 7.4%, $P = 0.0010$), undergo blood transfusion (5.3% vs 3.8%, $P < 0.0001$), and require conversion of cardiac rhythm (2.2% vs 0.9%, $P = 0.0011$). No significant difference was noted in mortality among transfers, hospital LOS, ICU LOS, time mechanically ventilated, frequency of neurosurgical intervention, need for laparotomy or thoracotomy, or disposition at discharge.

In the group without head injury, 42,562 patients were matched 1:1, and outcomes were analyzed (Table 4). Hypothermia

TABLE 3. Outcomes in Patients With Head Injury With Multisystem Trauma Before and After Propensity Score Matching

	Nonisolated Head Injury Before Matching				Nonisolated Head Injury After Matching		
Variables	**Normothermic (n = 41,562)**	**Hypothermic (n = 7908)**	**Total (n = 49,470)**	***P***	**Normothermic (n = 2345)**	**Hypothermic (n = 2345)**	***P***
Mortality	477 (1.2%)	637 (8.1%)	1114 (2.3%)	<0.0001	99 (4.2%)	176 (7.5%)	<0.0001
Mortality for transfers	93 (0.2%)	219 (2.8%)	312 (0.6%)	<0.0001	20 (0.9%)	53 (2.3%)	0.1072
Discharge				<0.0001			0.4800
Home	36,269 (87.3%)	5835 (73.8%)	42,104 (85.1%)		1855 (79.1%)	1777 (75.8%)	
Other	4784 (11.5%)	1430 (18.1%)	6214 (12.6%)		387 (16.5%)	392 (16.7%)	
Length of hospital stay, d	3.1 (5.8)	5 (9.2)	3.4 (6.5)	<0.0001	4.9 (8.7)	5 (8.7)	0.5928
Length of ICU stay, d	3.6 (5.8)	5.4 (8.2)	4 (6.4)	<0.0001	5.5 (8.6)	5.3 (7.2)	0.5420
Time on ventilator, d	4.8 (7.3)	5.6 (9.1)	5.1 (8.0)	0.0001	5.8 (8.8)	5.4 (7.0)	0.3197
Neurosurgical intervention	1657 (4.0%)	771 (9.8%)	2428 (4.9%)	<0.0001	201 (8.6%)	234 (10.0%)	0.0980
Endotracheal tube	1773 (4.3%)	955 (12.1%)	2728 (5.5%)	<0.0001	173 (7.4%)	240 (10.2%)	0.0010
Exploratory thoracotomy	15 (0.0%)	13 (0.2%)	28 (0.1%)	<0.0001	1 (0.0%)	5 (0.2%)	0.2043
Laparotomy	288 (0.7%)	169 (2.1%)	457 (0.9%)	<0.0001	32 (1.4%)	48 (2.1%)	0.0858
Blood transfusion	754 (1.8%)	433 (5.5%)	1187 (2.4%)	<0.0001	90 (3.8%)	124 (5.3%)	0.0237
Conversion of cardiac rhythm	103 (0.3%)	165 (2.1%)	268 (0.5%)	<0.0001	21 (0.9%)	51 (2.2%)	0.0011

Mean and SD for continuous variables. *P* values prematching calculated using independent *t* tests; *P* values postmatching calculated using paired *t* tests. Count and percentage for categorical variables. *P* values prematching calculated using χ^2 tests; *P* values postmatching calculated using generalized linear models.

TABLE 4. Outcomes in Patients Without Head Injury Before and After Propensity Score Matching

	Before Matching				After Matching		
Variables	**Normothermic (n = 226,303)**	**Hypothermic (n = 60,599)**	**Total (n = 286,902)**	***P***	**Normothermic (n = 21,281)**	**Hypothermic (n = 21,281)**	***P***
Mortality	330 (0.2%)	502 (0.2%)	832 (0.3%)	<0.0001	61 (0.3%)	144 (0.7%)	<0.0001
Mortality for transfers	35 (0.0%)	88 (0.2%)	123 (0.0%)	0.0059	10 (0.05%)	22 (0.1%)	0.0222
Discharge				<0.0001			<0.0001
Home	206,089 (91.1%)	53,443 (91.1%)	259,532 (90.5%)		20,045 (94.2%)	19,564 (91.9%)	
Other	19,745 (8.7%)	6576 (8.7%)	26,321 (9.2%)		1166 (5.5%)	1568 (7.4%)	
Length of hospital stay, d	2.4 (3.6)	2.7 (5.1)	2.5 (4)	<0.0001	3 (3.5)	3 (4.7)	<0.0001
Length of ICU stay, d	2.7 (4.1)	3.6 (5.3)	2.9 (4.5)	<0.0001	3 (4.9)	4 (5.2)	<0.0001
Time on ventilator, d	3.1 (5.7)	4.2 (6.9)	3.4 (6.1)	<0.0001	3 (6.1)	4 (6.7)	<0.0001
Endotracheal tube	2378 (1.1%)	1328 (2.2%)	3706 (1.3%)	<0.0001	257 (1.2%)	426 (2.0%)	<0.0001
Exploratory thoracotomy	170 (0.1%)	146 (0.2%)	316 (0.1%)	<0.0001	22 (0.1%)	54 (0.3%)	0.0007
Laparotomy	3248 (1.4%)	1303 (2.2%)	4551 (1.6%)	<0.0001	330 (1.6%)	456 (2.1%)	<0.0001
Blood transfusion	2620 (1.2%)	1231 (2.0%)	3851 (1.3%)	<0.0001	265 (1.3%)	480 (2.3%)	<0.0001
Conversion of cardiac rhythm	148 (0.1%)	200 (0.3%)	348 (0.1%)	<0.0001	27 (0.1%)	56 (0.3%)	0.0027

Mean and SD for continuous variables. *P* values prematching calculated using independent *t* tests; *P* values postmatching calculated using paired *t* tests. Count and percentage for categorical variables. *P* values prematching calculated using χ^2 tests; *P* values postmatching calculated using generalized linear models.

was associated with an increased risk of mortality compared with normothermia (0.7% vs 0.3%, $P < 0.0001$). Among patients transferred between facilities, hypothermia was associated with increased mortality (0.1% vs 0.05%, $P = 0.0222$). For patients who survived, hypothermic patients were more likely to be discharged to another facility compared with normothermic patients (7.4% vs 5.5%, $P < 0.0001$). Hypothermic patients were more likely than normothermic patients to require intubation (2.0% vs 1.2%, $P < 0.0001$), undergo thoracotomy (0.3% vs 0.1%, $P = 0.0007$), undergo exploratory laparotomy (2.1% vs 1.6%, $P < 0.0001$), undergo blood transfusion (2.3% vs 1.3%, $P < 0.0001$), and require conversion of cardiac rhythm (0.3% vs 0.1%, $P = 0.0027$).

We also analyzed outcomes in patients with hypothermia based on the presence or absence of head injury (Fig. 1). Hypothermic patients were assigned a propensity score and then divided into groups based on presence or absence of head injury. Following 1:1 matching, outcomes in 17,938 patients with and without head injury were analyzed (Table 5). The presence of head injury was associated with increased mortality (2.8% vs 1.4%). Among patients transferred between facilities, the presence of head injury was associated with increased mortality (0.8% vs 0.2%, $P = 0.0247$). Patients with head injury were also more likely to be discharged to another facility (11.5% vs 9.7%, $P < 0.0001$). Patients without head injury had a higher rate of blood transfusion (4.0% vs 2.7%, $P < 0.0001$), longer hospital LOS (3.6 vs 3.2 days,

TABLE 5. Outcomes in Patients With Hypothermia Before and After Propensity Score Matching

	Before Matching				After Matching		
Variables	**No Head Injury (n = 60,599)**	**Head Injury (n = 30,957)**	**Total (n = 91,556)**	***P***	**No Head Injury (n = 8969)**	**Head Injury (n = 8969)**	***P***
Mortality	502 (0.8%)	1844 (6.0%)	2346 (2.6%)	<0.0001	128 (1.4%)	251 (2.8%)	<0.0001
Mortality for transfers	88 (0.2%)	593 (1.9%)	681 (0.7%)	<0.0001	21 (0.2%)	71 (0.8%)	0.0247
Discharge				<0.0001			<0.0001
Home	53,443 (88.2%)	23,343 (75.4%)	76,786 (83.9%)		7972 (88.9%)	7685 (85.7%)	
Other	6576 (10.9%)	5745 (18.6%)	12,321 (13.5%)		868 (9.7%)	1030 (11.5%)	
Length of hospital stay, d	2.7 (5.1)	4.5 (8.1)	3.3 (6.3)	<0.0001	3.6 (6.1)	3.2 (5.4)	<0.0001
Length of ICU stay, d	3.6 (5.3)	4.8 (7.3)	4.4 (6.7)	<0.0001	4.4 (6.1)	3.5 (5.4)	0.0002
Time on ventilator, d	4.2 (6.9)	5.5 (8.8)	5.1 (8.3)	<0.0001	5 (7.6)	4.2 (6.8)	0.0504
Neurosurgical interventions	26 (0.0%)	2950 (9.5%)	2976 (3.3%)	<0.0001	12 (0.1%)	476 (5.3%)	<0.0001
Exploratory thoracotomy	146 (0.2%)	30 (0.1%)	176 (0.2%)	<0.0001	36 (0.4%)	6 (0.1%)	0.0002
Laparotomy	1303 (2.2%)	430 (1.4%)	1733 (1.9%)	<0.0001	266 (3.0%)	50 (0.6%)	<0.0001
Blood transfusion	1231 (2.0%)	1629 (5.3%)	2860 (3.1%)	<0.0001	355 (4.0%)	240 (2.7%)	<0.0001
Conversion of cardiac rhythm	200 (0.3%)	450 (1.5%)	650 (0.7%)	<0.0001	50 (0.6%)	69 (0.8%)	0.0826

Mean and SD for continuous variables. *P* values prematching calculated using independent *t* tests; *P* values postmatching calculated using paired *t* tests. Count and percentage for categorical variables. *P* values prematching calculated using χ^2 tests; *P* values postmatching calculated using generalized linear models.

$P < 0.0001$), and longer ICU LOS (4.4 vs 3.5 days, $P = 0.0002$). There was no difference between the 2 groups in duration of mechanical ventilation or conversion of cardiac rhythm.

Mortality was also examined with respect to age group (see Table, Supplemental Digital Content 5, which shows age group and hypothermia by mortality, http://links.lww.com/PEC/A298). The highest rate of mortality in hypothermic and normothermic patients occurred in the 10- to 18-year age group, whether head injury was present or absent.

DISCUSSION

Our study demonstrates that hypothermia is associated with increased mortality in pediatric trauma patients. In addition, hypothermia was associated with an increased rate of endotracheal intubation, rate of blood transfusion, and rate of cardiac rhythm conversion. Hypothermia contributes to increased morbidity and mortality by inducing cardiac dysrhythmias, decreasing cardiac output, exacerbating coagulopathy, worsening acidosis, and causing a left shift on the oxyhemoglobin dissociation curve.[22–24] Pediatric patients have a higher body surface area–to–mass ratio, putting them at higher risk of environmental heat loss. Prolonged environmental exposure or prolonged extrication can potentially contribute to hypothermia. Trauma resuscitation frequently involves nonwarmed intravenous fluids that can exacerbate hypothermia.

Several studies in the past have proposed benefits to inducing hypothermia in cases of severe traumatic brain injury.[25–27] However, a more recent phase 3, randomized controlled trial evaluating the effects of induced moderate hypothermia in pediatric trauma patients was stopped early because of futility.[28] In addition, the most recent guidelines released by the Brain Trauma Foundation in 2016 do not recommend early, short-term prophylactic hypothermia for the treatment of adult patients with traumatic brain injury.[29]

Trauma scoring systems were developed to aid hospital personnel in determining trauma triage level as well as predicting the level of trauma care needed. The most widely used system is the Revised Trauma Score, which incorporates respiratory rate, systolic blood pressure, and GCS score to calculate a prehospital triage score.[30] The PTS was designed specifically for the pediatric trauma patient. Parameters including weight, airway assessment, systolic blood pressure, central nervous system (level of alertness), open wound, and skeletal injury are used to calculate a prehospital score.[5,6] Several other classification systems such as the Prehospital Index and Trauma Triage Rule also exist. Several components of each of these scoring systems have been incorporated into guidelines for triage of injured patients in the field and are commonly used by local emergency medical services.[4,31] Temperature is not included in any of these scoring systems, nor is it included in the most recent guidelines for triaging patients in the field.

We have shown hypothermia to be an independent risk factor for mortality in pediatric trauma patients. These findings are consistent with research in the adult literature, as well as 2 smaller pediatric studies. Waibel et al[15] performed a study at a rural level I trauma center and found hypothermia as a risk factor for mortality with an odds ratio of 2.41. Sundberg et al[14] also performed a study at a large, urban level I trauma center. They found hypothermia to be a significant risk factor for mortality. Both of these studies were performed at single sites and had a much smaller population size compared with our analysis.

There were several limitations to our study. This was a retrospective analysis of a database; thus, inaccurate or missing data could potentially affect our findings. Second, we were unable to identify the route of temperature measurement. This could potentially affect our findings because nonrectal temperatures might not accurately reflect core temperature.[32] Third, we were unable to discern whether any rewarming or cooling measures were performed prior to the initial recorded temperature. In addition, we were unable to determine from this study if hypothermia is causative of worse outcomes or if it is a marker of severe injury and that the injury itself leads to worse outcomes.

Finally, the NTDB reports only cases in the year that they occurred. Thus, we are not able to control for seasonal variation. We attempted to minimize this impact as much as possible by controlling for geographic regions with similar weather patterns. However, controlling for the time of year would provide a more accurate analysis.

We have demonstrated that hypothermia is a significant, independent predictor of mortality in pediatric trauma patients. Currently, temperature is not a parameter used in any of the trauma scoring systems. Further studies are indicated to evaluate the incorporation of temperature into the PTS not only to help predict injury severity and mortality, but also to improve appropriate and expeditious patient transfer to pediatric trauma centers and potentially facilitate earlier intervention.

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