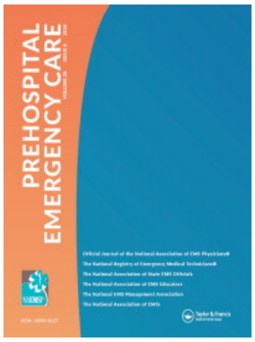

Prehospital Emergency Care

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ipec20

Feasibility and Safety of Targeted Temperature Management During Interhospital Transport of Post-Cardiac Arrest Patients

Ki Hong Kim, Young Sun Ro, Seulki Choi, Minwoo Kim & Sang Do Shin

To cite this article: Ki Hong Kim, Young Sun Ro, Seulki Choi, Minwoo Kim & Sang Do Shin (13 Nov 2024): Feasibility and Safety of Targeted Temperature Management During Interhospital Transport of Post-Cardiac Arrest Patients, Prehospital Emergency Care, DOI: 10.1080/10903127.2024.2420881

To link to this article: https://doi.org/10.1080/10903127.2024.2420881

PREHOSPITAL EMERGENCY CARE
https://doi.org/10.1080/10903127.2024.2420881

Feasibility and Safety of Targeted Temperature Management During Interhospital Transport of Post-Cardiac Arrest Patients

Ki Hong Kim, Young Sun Ro, Seulki Choi, Minwoo Kim, and Sang Do Shin

Department of Emergency Medicine, Seoul National University Hospital and College of Medicine, Seoul, Korea

ABSTRACT

Objectives: Early initiation of targeted temperature management (TTM) is crucial for post-resuscitation care. Although TTM is initiated prior to transport and continued during interhospital transport (IHT), its feasibility and safety during IHT for cardiac arrest patients have not been thoroughly assessed. This study aims to evaluate the feasibility and safety of interhospital TTM for post-resuscitation patients.

Methods: A retrospective analysis of post-cardiac arrest patients transported by a dedicated critical care transport team between January 2016 and April 2023 was conducted. Adult patients resuscitated from cardiac arrest without mental recovery were enrolled. The study population was divided into those who received TTM during IHT (IHT-TTM group) and those who did not (non-IHT-TTM group). The primary outcome was body temperature drop during transport, with hypotension, or desaturation during transport considered as secondary outcomes. Multivariable conditional logistic regression analysis was performed after frequency matching.

Results: Among 593 post-cardiac arrest patients, 332 were included in the analysis after exclusions. Of these, 44 (13.3%) received TTM during IHT. Conditional logistic regression analysis showed significantly higher likelihood for a drop in body temperature during IHT for the IHT-TTM group, with an odds ratio (OR) of 12.91 (95%CI: 5.28–31.53). No significant association was found for hypotension (OR (95%CI): 0.72 (0.13–3.97)), or desaturation during IHT (0.65 (0.15–2.82)).

Conclusions: Administration of TTM during IHT for post-cardiac arrest patients appears to be feasible and safe. These findings support the implementation of dedicated critical care transport systems capable of providing TTM during IHT for post-cardiac arrest patients.

ARTICLE HISTORY
Received 3 May 2024
Revised 20 September 2024
Accepted 7 October 2024

Introduction

Sudden cardiac arrest is one of the global health burdens with high mortality and grave neurological prognosis (1, 2). Long-term neurological recovery remains low despite numerous research efforts on post-resuscitation care (3, 4). The socioeconomic burden associated with the rehabilitation and care of cardiac arrest survivors is significant, including a low rate of return to work and a high rate of nursing home admissions (5–7).

Reperfusion injury after the return of spontaneous circulation (ROSC) has been identified as a factor exacerbating inflammation in brain tissue after cardiac arrest (8). Targeted temperature management (TTM), extensively studied over the years, has shown efficacy in preventing reperfusion injury and improving neurological outcomes, with the maintenance of target body temperature (32–36 °C) during management demonstrating more favorable outcomes (9–13). Early initiation of TTM following ROSC is also recognized as crucial for better patient outcomes (14). In Korea, TTM is administered in approximately 500–700 cases (8–12%) annually for out-of-hospital cardiac arrest with ROSC, specifically when it is indicated and feasible (15). However, it has been observed that TTM may lead to clinical deterioration, such as hypotension or hypoxia, due to autonomic responses to low body temperature (16–18).

Interhospital transport (IHT) for cardiac arrest patients with ROSC, aimed at post-resuscitation care, is often critical but may result in deteriorated clinical outcomes (19). It is known that the provision of adequate critical care on ambulance during transport is limited (20), leading to potential fluctuations in physiological parameters that can impact patient outcomes (21). While TTM has been administered during IHT in some cases (22, 23), its feasibility and safety for cardiac arrest patients have not been thoroughly assessed.

We hypothesized that the establishment of a dedicated critical care transport team in 2016, along with the implementation of a TTM protocol for unconscious adult post-resuscitation cardiac arrest patients eligible for TTM, would enable TTM to be administered effectively and safely during IHT for these patients. The purpose of this study is to evaluate the feasibility and safety of TTM during IHT for cardiac arrest patients with ROSC. Our assessment focuses on analyzing a drop in body temperature, achievement of target temperature, and deterioration of vital signs during IHT.

CONTACT Young Sun Ro Ro.youngsun@gmail.com

Methods

Study Design and Setting

This study was a retrospective observational study, utilizing data from a dedicated IHT system.

Seoul Metropolitan City, the capital of Korea, with a population of approximately 10 million and an area of 605.2 km^2, served as the study setting. Approximately 1.7 million patients visited the 66 emergency departments (EDs) within the city in 2023 (24). This study complied with the Declaration of Helsinki, and its protocol was approved by the Institutional Review Board of the study site with a waiver of informed consent (IRB No. H-2001-015-1090). All methods were performed in accordance with relevant guidelines and regulations.

In Korea, the majority of IHT is primarily handled by private emergency medical services (EMS) agencies, responding to requests from the departing hospital. Regulations outlined in the Emergency Medical Services Act dictate that during IHT, at least one emergency medical technician (EMT) must be present on board, in addition to the ambulance driver. Physicians or nurses typically do not accompany the patient during transport unless the patient is in a life-threatening condition or in an exceptionally special circumstance. Transporting EMTs can receive medical oversight from the physician at the departing hospital. Transportation fees are paid out-of-pocket and are not covered by the National Health Insurance in Korea. These fees are determined solely based on the distance of IHT. Due to the lack of an official fee-for-service charge for clinical services or healthcare providers during transport, private EMS agencies often operate with only one EMT on board and may provide minimal monitoring or management during transport. Consequently, there are often challenges in adequately managing IHT for critically ill patients by private EMS agencies.

In response to this challenge, the Seoul Mobile Intensive Care Unit (SMICU) was established as a dedicated public critical care transport system for IHT within Seoul Metropolitan City since 2016. Funded by the Seoul metropolitan government and operated by Seoul National University Hospital, SMICU operates 24 h a day, seven days a week, to cover IHT for critically ill patients. Each SMICU team comprises an on-duty emergency physician, nurse, and level 1 EMT, ensuring comprehensive care during transport. Detailed information on SMICU operation is available in a previous study (25). SMICU was dispatched immediately for patients requiring critical care transport for IHT. However, to address the growing demand and enhance response capabilities, system expansion was necessary. Consequently, SMICU operations expanded to two teams in March 2021 and four teams in March 2023, with standby ambulance stations for each region (north-west, north-east, south-west, and south-east) within Seoul Metropolitan City since 2023.

The interhospital TTM protocol for cardiac arrest patients had specific inclusion and exclusion criteria. Inclusion criteria comprised individuals over 18 years of age who achieved ROSC within six hours and lacked a meaningful response to verbal commands. It was additionally recommended that if the requesting hospital had already initiated TTM before interhospital transport, further continuation should be considered. Exclusion criteria for interhospital TTM included cardiac arrest patients with active bleeding, suspected traumatic cardiac arrest, pregnancy, body weight below 35 kilograms, hemodynamical instability determined by the attending physician, or instances where a Do-not-resuscitate order was in place or patient care-giver refusal was documented. In the SMICU, external cooling devices such as the Arctic Sun and BrainCool are routinely used for interhospital TTM, regardless of the cooling methods employed by the requesting hospital. All physiological parameters, including body temperature, are recorded every 5–10 min by a nurse or EMT during IHT.

Data Source

The study utilized the SMICU IHT database, which was independently developed for quality control and comprises a comprehensive range of variables encompassing various aspects of the transportation process. These variables include demographics, time-related variables, information on the request and receiving hospitals, reasons for IHT, chief complaints and diagnoses at the requesting hospital, mental status and physiological parameters monitored during transport, point-of-care test results, medical procedures conducted during IHT, and events during ambulance transport. Additionally, the database included information on the indications and contraindications for TTM, which were recorded when considering the patient for interhospital TTM. Data entries into the database were made by physicians, nurses, and EMTs involved in the transportation process. To ensure the quality of the data, regular reviews were conducted by an administrative nurse.

Study Population

The study population consisted of adult post- cardiac arrest patients, including both out-of-hospital and in-hospital arrests, who were interhospital transported by SMICU between January 2016 and April 2023. Pediatric patients, those without recorded body temperature data before, during, or after IHT, and patients who received warming interventions were excluded from the analysis.

Outcomes

The primary outcome was the drop in body temperature during IHT (including decreases of up to $-0.1\,°C$). Secondary outcomes included the achievement of targeted temperature ($<36\,°C$), as well as occurrences of hypotension (systolic blood pressure <90 mmHg) and desaturation (pulse oximetry $<90\%$) events during IHT.

Exposure and Variables

The variable of interest was whether TTM was administered in the ambulance during IHT. Typically, the initiation of TTM is determined by the attending physicians at both the requesting and receiving hospitals, while the decision to maintain TTM during transport is made by the physician from the SMICU.

Demographic data collected included age, sex, and chief complaint (such as cardiac arrest, coronary symptoms, dyspnea, altered mental status, etc.), as well as past medical history. Information related to IHT was gathered, including the reason for interhospital transfer, patient location at the requesting hospital and receiving hospital, elapsed time intervals during IHT (call to arrival at the requesting hospital, from arrival at the requesting hospital to departure, and from departure to arrival at the receiving hospital), monitors and devices applied at the requesting hospital, medication during IHT, and events/managements in the ambulance during IHT (such as arrhythmia, endotracheal tube management, patient irritability, intravenous catheter or other medical device malfunction, and increase or decrease of vasopressors). Physiological parameters monitored during IHT included systolic blood pressure, heart rate, pulse oximetry, and body temperature.

Statistical Analysis

Demographics and clinical findings were described and compared according to the implementation of TTM during IHT (IHT-TTM). Categorical variables were demonstrated by frequency and proportion, and continuous variables by median and interquartile ranges. Chi-square test for categorical variables and Wilcoxon rank-sum test for continuous variables were used.

To assess the feasibility and safety of interhospital TTM for cardiac arrest patients with ROSC, a two-to-one frequency matching between the no-IHT-TTM group and the IHT-TTM group was conducted based on age, sex, systolic blood pressure and body temperature at the requesting hospital. Conditional logistic regression analysis was conducted to calculate odds ratio and 95% confidence intervals for primary and secondary outcomes. p-value under 0.05 was considered as statistically significant. All statistical analysis was conducted by R version 3.5 (R Foundation for Statistical Computing; Vienna, Austria).

Results

Out of 593 post-cardiac arrest patients interhospital transported by SMICU, 332 patients were included in the final analysis after excluding 92 pediatric patients, 164 patients without information about body temperature (21 at the time of departure from the requesting hospital, 87 in the ambulance, and 56 at the time of arrival at the receiving hospital), and 5 patients who received warming during IHT (Figure 1).

Among the study population of 332 post-cardiac arrest patients, 44 patients (13.3%) received interhospital TTM and were included in the IHT-TTM group, while 288 patients (86.7%) were included in the no-IHT-TTM group. Patients in the IHT-TTM group were more likely to be younger and were transferred due to a lack of ICU bed. They were also more likely to receive intensive monitoring with mechanical ventilation (Table 1).

Body temperature was lower in the IHT-TTM group compared to the no-IHT-TTM group, both at the beginning and end of IHT: 34.9 (33.8–35.7) versus 36.4 (35.7–37.2) at the beginning of IHT, and 34.5 (33.6–35.5) versus 36.4 (35.6–37.1) at the end of IHT (both p-value <0.01). The proportion of achievement of targeted temperature (36 °C) was higher in the IHT-TTM group: 37 (84.1%) versus 118 (41.0%), p-value <0.01. There was no significant difference in the occurrence of hypotension or desaturation at the beginning and end of IHT. Additionally, no patient had a body temperature below 32 °C during the IHT. The time from departure from the requesting hospital to arrival at the receiving hospital was 17 (12–25) minutes for the no-IHT-TTM group and 20 (15–26) minutes for the IHT-TTM group ($p = 0.19$) (Table 2).

After two-to-one matching, it was observed that the body temperature at the beginning and end of IHT remained lower in the IHT-TTM group compared to the matched no-IHT-TTM group. Additionally, changes in body temperature were found to be significantly larger in the IHT-TTM group: −0.2 (−0.4 to −0.1) versus 0 (0.0 to 0.0), p-value <0.01 (Table 3).

Conditional logistic regression analysis showed significantly higher odds for a drop in body temperature (even as low as −0.1 °C) during IHT for the IHT-TTM group, with an odds ratio of 12.91 (95%CI: 5.28–31.53). However, there were no significant differences between the study groups in achieving the targeted temperature of 36 °C, hypotension, or desaturation during IHT. The odds ratios were 1.45 (0.33–6.32) for the achievement of target temperature, 0.60 (0.14–2.58) for hypotension during IHT, and 0.73 (0.18–2.91) for desaturation during IHT (Table 4).

Discussion

Among cardiac arrest patients interhospital transported for post-resuscitation care by the dedicated critical care transport team, TTM during IHT successfully lowered body temperature without an increase in adverse events such as hypotension and desaturation. These results suggest that TTM during IHT appears to be feasible and safe for post-cardiac arrest patients. Implementing TTM during transport could aid in the early initiation or maintenance of target body temperature, potentially reducing reperfusion injury after cardiac arrest.

The prompt initiation of TTM could potentially improve neurological outcomes in post-cardiac arrest patients, and early implementation should be considered when indicated (14, 26). However, TTM has the potential to compromise the hemodynamic status of these patients due to autonomic responses to low body temperature (27). Therefore, continuous monitoring of various physiological parameters, including body temperature, during TTM is necessary to promptly manage any adverse events that may occur. Physicians may hesitate to initiate TTM for patients requiring transfer to another hospital due to concerns regarding potential

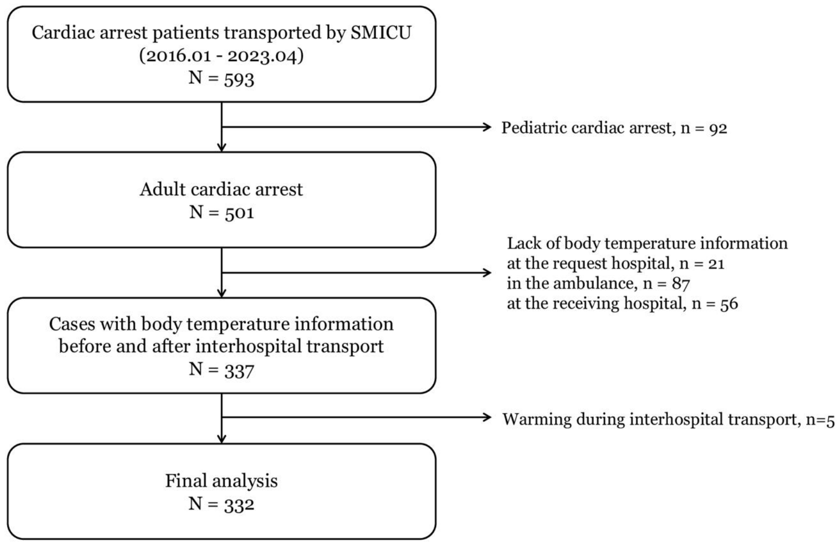

Figure 1. Study population.
SMICU, Seoul Mobile Intensive Care Unit.

interruptions in cooling during ambulance transport, which could lead to delays in achieving the target temperature (28). Nonetheless, this study suggests that TTM administered by a dedicated critical care transport team during IHT is both feasible and safe for post-cardiac arrest patients. Considering safety and ease of application, external device cooling may be a more practical option for ambulance settings compared to other cooling methods such as external conventional cooling, intravascular cooling, or intra-cavitary cooling (29, 30).

The 2023 AHA (American Heart Association) guidelines update recommends maintaining a constant temperature between 32 °C and 37.5 °C during post-arrest temperature control (31). However, the recent Korean Guidelines for Cardiopulmonary Resuscitation still recommend maintaining a temperature between 32 °C and 36 °C (32). This discrepancy highlights the ongoing debate over the optimal target temperature for post-cardiac arrest care. Although the optimal target temperature remains controversial, especially regarding neurological outcomes, TTM within the range specified by guidelines is generally considered beneficial for patients with specific indications.

In this study, the IHT-TTM group presented higher proportions of receiving intensive monitoring, continuous intravenous infusion of medication, and mechanical ventilation at the time of departure from the requesting hospital compared to the no-IHT-TTM group. Despite this, the occurrence of adverse events, including vasopressor or ventilator adjustment, was not significantly higher than in the no-IHT-TTM group (38.6% in the IHT-TTM group versus 36.1% in the no-IHT-TTM group, *p*-value 0.88). We hypothesize that a dedicated critical care transport team may mitigate hemodynamic adverse events by adjusting patients' management at the requesting hospital and maintaining the level of care during transport.

A critical care transport system has been established to ensure the safety of critically ill patients during IHT (20). It is recommended that a dedicated critical care team with experience and specialized training be implemented for such transports (33, 34). The SMICU team, which includes emergency specialists, nurses, and EMTs with specialized training, adheres to comprehensive protocols designed for various critical conditions, including TTM. These protocols ensure that most medical procedures performed in the intensive care unit can be feasibly and safely carried out during IHT, thus supporting continuous management and life-saving treatment of patients. The ambulance is equipped with nearly all necessary equipment and supplies for resuscitation and procedures. Given these considerations, a tailored training program for dedicated critical care transport teams is essential. A previous study reported a low incidence of adverse events during the IHT of neonates with hypoxic-ischemic encephalopathy when transported by a trained critical care transport team (35).

The study findings suggest that TTM for post-cardiac arrest patients during IHT by a dedicated critical care transport team is safe and feasible. Providing TTM during IHT may lead to a decrease in body temperature for these patients. However, there was no significant difference in achieving the targeted temperature of 36 °C of between the two groups, which may be attributed to the relatively short transport time interval. Nevertheless, the study findings indicate that providing continuous TTM during IHT for eligible patients leads to a reduction in body temperature, which may contribute to improved neurological outcomes. A large-scale clinical trial is needed to further elucidate the effect of IHT TTM on neurological recovery for post-cardiac arrest patients. Therefore, it would be recommended not to delay initiating TTM early due to IHT process for physicians.

Limitations

This study has several limitations. First, the study population included patients with complete information regarding body temperature at all three time points: at the time of departure from the requesting hospital, during transport in the

Table 1. Demographic information according to targeted temperature management during interhospital transport.

	Total N (%)	IHT-TTM N (%)	No IHT-TTM N (%)	*p*-value
Total	332	44	288	
Age, years, median, IQR	64 (52–75)	58 (39–72)	65 (53–76)	0.02
Sex, male	229 (69.0)	33 (75.0)	196 (68.1)	0.45
Chief complaint				<0.01
Cardiac arrest	248 (74.7)	30 (68.2)	218 (75.7)	
Altered mentality/seizure	34 (10.2)	5 (11.4)	29 (10.1)	
Chest pain/coronary symptom	7 (2.1)	1 (2.3)	6 (2.1)	
Dyspnea	21 (6.3)	1 (2.3)	20 (6.9)	
General symptom	14 (4.2)	1 (2.3)	13 (4.5)	
Asphyxia/hanging	8 (2.4)	6 (13.6)	2 (0.7)	
Past medical history				
Hypertension	107 (32.2)	16 (36.4)	91 (31.6)	0.65
Diabetes mellitus	93 (28.0)	15 (34.1)	78 (27.1)	0.43
Cancer	57 (17.2)	4 (9.1)	53 (18.4)	0.19
Heart disease	71 (21.4)	7 (15.9)	64 (22.2)	0.45
Liver disease	10 (3.0)	0 (0.0)	10 (3.5)	0.43
Reason for interhospital transfer				0.03
Lack of ICU bed	201 (60.5)	32 (72.7)	169 (58.7)	
For operation/intervention	67 (20.2)	7 (15.9)	60 (20.8)	
Others	64 (19.3)	5 (11.4)	59 (20.5)	
Patient location of request hospital				0.19
Emergency room	240 (72.3)	37 (84.1)	203 (70.5)	
ICU	79 (23.8)	6 (13.6)	73 (25.3)	
Others	13 (3.9)	1 (2.3)	12 (4.2)	
Device at request hospital				
Arterial blood pressure monitor	211 (63.6)	36 (81.8)	175 (60.8)	0.01
Central venous catheter	195 (58.7)	37 (84.1)	158 (54.9)	<0.01
High-flow nasal cannula	2 (0.6)	0 (0.0)	2 (0.7)	1.00
Mechanical ventilator	256 (77.1)	40 (90.9)	216 (75.0)	0.03
Chest tube	6 (1.8)	0 (0.0)	6 (2.1)	0.72
Mechanical CPR device	8 (2.4)	1 (2.3)	7 (2.4)	1.00
ECMO	18 (5.4)	1 (2.3)	17 (5.9)	0.53
TTM	35 (10.5)	34 (77.3)	1 (0.3)	<0.01
Patient location of receiving hospital				0.42
Emergency room	237 (71.4)	35 (79.5)	202 (70.1)	
ICU	69 (20.8)	7 (15.9)	62 (21.5)	
Others	26 (7.8)	2 (4.5)	24 (8.3)	
Events/managements during IHT				0.08
Arrhythmia	7 (2.1)	0 (0.0)	7 (2.4)	
Endotracheal tube manage/suction	4 (1.2)	1 (2.3)	3 (1.0)	
Patient irritability	9 (2.7)	2 (4.5)	7 (2.4)	
IV line disconnect/malfunction	7 (2.1)	0 (0.0)	7 (2.4)	
IV medication bolus administer	5 (1.5)	1 (2.3)	4 (1.4)	
Medical device malfunction	5 (1.5)	2 (4.5)	3 (1.0)	
Monitor temporarily unmeasurable	50 (15.1)	8 (18.2)	42 (14.6)	
Vasopressor dose reduction	4 (1.2)	1 (2.3)	3 (1.0)	
Vasopressor dose elevation	5 (1.5)	0 (0.0)	5 (1.7)	
Ventilator setting/airway change	25 (7.5)	2 (4.5)	23 (8.0)	
Others	83 (25.0)	18 (40.9)	65 (22.6)	
Continuous medication infusion during IHT				
Norepinephrine	177 (53.3)	30 (68.2)	147 (51.0)	0.05
Dopamine	36 (10.8)	4 (9.1)	32 (11.1)	0.89
Remifentanil	91 (27.4)	17 (38.6)	74 (25.7)	0.11
Midazolam	60 (18.1)	17 (38.6)	43 (14.9)	<0.01
Vasopressin	37 (11.1)	5 (11.4)	32 (11.1)	1.00
Dobutamine	23 (6.9)	4 (9.1)	19 (6.6)	0.77
Epinephrine	16 (4.8)	1 (2.3)	15 (5.2)	0.64
Dexmedetomidine	23 (6.9)	2 (4.5)	21 (7.3)	0.73
Vecuronium	24 (7.2)	9 (20.5)	15 (5.2)	<0.01
Nitroglycerin	11 (3.3)	2 (4.5)	9 (3.1)	0.97
Amiodarone	19 (5.7)	3 (6.8)	16 (5.6)	1.00
Propofol	25 (7.5)	6 (13.6)	19 (6.6)	0.18
Nicardipine	6 (1.8)	1 (2.3)	5 (1.7)	1.00

Abbreviations: IHT, interhospital transport; IQR, interquartile range; ICU, intensive care unit; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membranous oxygenation; TTM, targeted temperature management; IV, intravenous.

ambulance, and at the time of arrival at the receiving hospital. The 164 excluded patients did not undergo TTM and had insufficient records of temperature and vital signs during IHT. These patients were typically transported from the ED of the requesting hospital, with fewer instances of medical equipment application, such as arterial blood pressure monitoring, or continuous medication infusion, including inotropics. Although other characteristics were similar to the no-IHT-TTM group, there may still be inherent selection bias. Second, body temperature was primarily measured

Table 2. Comparison of time components and physiologic status before and after interhospital transport between study groups.

	Total N (%)	IHT-TTM N (%)	No IHT-TTM N (%)	*p*-value
Total	332	44 (13.3)	288 (86.7)	
Time intervals during IHT, minutes, median (IQR)				
Call to arrival at the request hospital	25 (17–35)	30 (20–37)	25 (17–34)	0.33
From arrival at the request hospital to departure	31 (24–41)	36 (32–45)	30 (24–40)	<0.01
From departure to arrival at the receiving hospital	17 (12–25)	20 (15–26)	17 (12–25)	0.19
Patient status at the point of IHT start				
Systolic blood pressure, mmHg, median (IQR)	122 (104–143)	130 (110–153)	121 (104–142)	0.25
Heart rate, beats per min, median (IQR)	93 (78–110)	87 (70–105)	96 (79–110)	0.11
Pulse oximetry, %, median (IQR)	99 (96–100)	99 (98–100)	99 (96–100)	0.40
Body temperature, Celsius, median (IQR)	36.2 (35.4–37.1)	34.9 (33.8–35.7)	36.4 (35.7–37.2)	<0.01
Patient status at the point of IHT end				
Systolic blood pressure, mmHg, median (IQR)	122 (106–140)	125 (113.5–147)	122 (105–138.5)	0.12
Systolic blood pressure < 90 mmHg	26 (7.8)	2 (4.5)	24 (8.3)	0.57
Heart rate, beats per min, median (IQR)	93 (76–109)	83 (69–103)	94 (78–109)	0.08
Heart rate > 100 beats/min	116 (34.9)	13 (29.5)	103 (35.8)	0.53
Heart rate < 60 beats/min	23 (6.9)	3 (6.8)	20 (6.9)	1.00
Pulse oximetry, %, median (IQR)	99 (97–100)	99 (98–100)	99 (97–100)	0.44
Pulse oximetry < 90%	15 (4.5)	2 (4.5)	13 (4.5)	1.00
Body temperature, Celsius, median (IQR)	36.2 (35.3–37.0)	34.5 (33.6–35.5)	36.4 (35.6–37.1)	<0.01
Body temperature < 36 °C	155 (46.7)	37 (84.1)	118 (41.0)	<0.01
Body temperature change during IHT	0.0 (-0.1 to 0.0)	−0.2 (-0.4 to −0.1)	0 (0.0 to 0.0)	<0.01

Abbreviations: IHT, interhospital transport; TTM, targeted temperature management; IQR, interquartile range.

Table 3. Comparison of time component and physiologic status before and after interhospital transport between study groups after 2:1 matching.

	IHT-TTM N (%)	No IHT-TTM N (%)	*p*-value
Total	43	86	
Age, years, median, IQR	58 (37–70)	60 (49–71)	0.32
Time intervals during IHT, minutes, median (IQR)			
Call to arrival at the request hospital	26 (20–37)	26 (16–37)	0.63
From arrival at the request hospital to departure	35 (31–45)	29 (23–37)	<0.01
From departure to arrival at the receiving hospital	21 (15–26)	17 (12–25)	0.14
Patient status at the point of IHT start			
Systolic blood pressure, mmHg, median (IQR)	129 (109–154)	122 (106–147)	0.74
Heart rate, beats per min, median (IQR)	84 (70–106)	94 (76–110)	0.40
Pulse oximetry, %, median (IQR)	99 (98–100)	99 (96–100)	0.23
Body temperature, Celsius, median (IQR)	34.8 (33.8–35.6)	35.5 (34.8–35.9)	<0.01
Patient status at the point of IHT end			
Systolic blood pressure, mmHg, median (IQR)	125 (112–146)	124 (104–144)	0.46
Systolic blood pressure < 90 mmHg	2 (4.7)	8 (9.3)	0.56
Heart rate, beats per min, median (IQR)	85 (69–104)	95 (73–109)	0.40
Heart rate > 100 beats/min	13 (30.2)	33 (38.4)	0.48
Heart rate < 60 beats/min	3 (7.0)	10 (11.6)	0.61
Pulse oximetry, %, median (IQR)	99 (98–100)	99 (97–100)	0.41
Pulse oximetry < 90%	2 (4.7)	4 (4.7)	1.00
Body temperature, Celsius, median (IQR)	34.5 (33.6–35.5)	35.5 (34.6–35.9)	<0.01
Body temperature < 36 °C	37 (86.0)	72 (83.7)	0.93
Body temperature change during IHT	−0.2 (−0.4 to −0.1)	0.0 (0.0 to 0.0)	<0.01

Abbreviations: IHT, interhospital transport; TTM, targeted temperature management; IQR, interquartile range.

Table 4. Conditional logistic regression analysis for drop of body temperature and deterioration of physiologic parameters for matched cohort.

	n/N (%)	Odds ratio (95% CI)
Body temperature drop		
TTM during IHT	33/43 (76.7)	12.91 (5.28–31.53)
No TTM during IHT	17/86 (19.8)	1.00
Achievement of target temperature		
TTM during IHT	37/43 (86.0)	1.45 (0.33–6.32)
No TTM during IHT	72/86 (83.7)	1.00
Hypotension during IHT		
TTM during IHT	5/43 (11.6)	0.60 (0.14–2.58)
No TTM during IHT	13/86 (15.1)	1.00
Desaturation during IHT		
TTM during IHT	3/43 (7.0)	0.73 (0.18–2.91)
No TTM during IHT	8/86 (9.3)	1.00

Abbreviations: CI, confidence interval; TTM, targeted temperature management; IHT, interhospital transport.

using a central body temperature monitor inserted through a Levin tube or Foley catheter for patients undergoing TTM during IHT, while an external tympanic membrane thermometer was used for patients not undergoing IHT-TTM. Although this practice was determined by clinical standards, where central body temperature monitoring is not routinely advised for patients not undergoing TTM, it may introduce measurement bias. Third, low body temperature often leads to inaccurate monitoring of peripheral pulse oximetry, which could affect the measurement of desaturation in the ambulance. Fourth, patient characteristics, including the cause of arrest and severity may differ between the study groups. Although frequency matching was conducted to adjust the probability for TTM, these differences may still impact the results. Additionally, information related to the cardiac arrest was based on handover from the requesting hospital, which was often unclear and incomplete, thereby limiting the analysis. Fifth, as a retrospective observational study, unmeasured bias could influence the results. Finally, the study was conducted in a metropolitan city in Korea, potentially limiting its generalizability to other settings.

Conclusions

Administration of TTM during interhospital transfer effectively reduced body temperature without increasing adverse events, such as hypotension and desaturation, in post-cardiac arrest patients transported for post-resuscitation care by a dedicated critical care transport team. These findings suggest that the implementation of dedicated critical care transport systems could safely provide TTM during interhospital transfer for post-cardiac arrest patients.

Acknowledgments

We would like to thank the SMICU team, for their contribution of interhospital critical care and data collection.

Authorship Statement

Y. S. Ro and K. H. Kim had full access to all of the data in the study and take responsibility for the integrity of the data as well as the accuracy of the data analysis. K. H. Kim, Y. S. Ro, and S. D. Shin were responsible for conceptualization of the study. Data curation was the responsibility of all the authors. K H. Kim was responsible for formal analysis, software, and writing of the original draft. K. H. Kim, and Y. S. Ro were responsible for investigation and methodology. Y. S. Ro and S. D. Shin were responsible for supervision of the study. S. Choi and M. Kim validated the study results. Y. S. Ro was responsible for the writing review and editing. The final manuscript was approved by all the authors.

Declaration of Generative AI in Scientific Writing

The authors did not use a generative artificial intelligence (AI) tool or service to assist with preparation or editing of this work. The authors take full responsibility for the content of this publication.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data Sharing Statement

The data for the study were obtained from the Seoul Mobile Intensive Care Unit (SMICU), but restrictions apply to the availability of these data and so are not publicly available, but are available from the corresponding author on reasonable request. This study complied with the Declaration of Helsinki, and its protocol was approved by the Institutional Review Board of the study site with a waiver of informed consent (IRB No. H-2001-015-1090). All methods were performed in accordance with relevant guidelines and regulations. De-identified data from this study are not available in a public archive. De-identified data from this study will be made available (as allowable according to institutional IRB standards) by emailing the corresponding author. Analytic code used to conduct the analyses presented in this study are not available in a public repository. They may be available by emailing the corresponding author. The authors agree to provide the full content of the manuscript on request by contacting the corresponding author.

References

1. Semsarian C, Ingles J, Wilde AA. Sudden cardiac death in the young: the molecular autopsy and a practical approach to surviving relatives. Eur Heart J. 2015;36(21):1290–6. doi:10.1093/eurheartj/ehv063.
2. Wong CX, Brown A, Lau DH, Chugh SS, Albert CM, Kalman JM, Sanders P. Epidemiology of sudden cardiac death: global and regional perspectives. Heart Lung Circ. 2019;28(1):6–14. doi:10.1016/j.hlc.2018.08.026.
3. Chin YH, Yaow CYL, Teoh SE, Foo MZQ, Luo N, Graves N, Ong MEH, Ho AFW. Long-term outcomes after out-of-hospital cardiac arrest: a systematic review and meta-analysis. Resuscitation. 2022;171:15–29. doi:10.1016/j.resuscitation.2021.12.026.
4. Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Chang AR, Cheng S, Delling FN, et al. Heart Disease and Stroke Statistics-2020 update: a report from the American Heart Association. Circulation. 2020;141(9):e139–596. doi:10.1161/CIR.0000000000000757.
5. Møller S, Wissenberg M, Søndergaard K, Kragholm K, Folke F, Hansen CM, Ringgren KB, Andersen J, Lippert F, Møller AL, et al. Long-term outcomes after out-of-hospital cardiac arrest in relation to socioeconomic status. Resuscitation. 2021;167:336–44. doi:10.1016/j.resuscitation.2021.07.015.
6. Yoo KH, Cho Y, Oh J, Lee J, Ko BS, Kang H, Lim TH, Lee SH. Association of socioeconomic status with long-term outcome in survivors after out-of-hospital cardiac arrest: nationwide population-based longitudinal study. JMIR Public Health Surveill. 2023;9:e47156. doi:10.2196/47156.
7. Paratz ED, Rowsell L, Zentner D, Parsons S, Morgan N, Thompson T, James P, Pflaumer A, Semsarian C, Smith K, et al. Cardiac arrest and sudden cardiac death registries: a systematic review of global coverage. Open Heart. 2020;7(1):e001195. doi:10.1136/openhrt-2019-001195.
8. Neumar RW, Nolan JP, Adrie C, Aibiki M, Berg RA, Böttiger BW, Callaway C, Clark RSB, Geocadin RG, Jauch EC, et al. Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication. A consensus statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council. Circulation. 2008;118(23):2452–83. doi:10.1161/CIRCULATIONAHA.108.190652.
9. Donnino MW, Andersen LW, Berg KM, Reynolds JC, Nolan JP, Morley PT, Lang E, Cocchi MN, Xanthos T, Callaway CW, et al. Temperature management after cardiac arrest: an advisory statement by the Advanced Life Support Task Force of the International Liaison Committee on Resuscitation and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Resuscitation. 2016;98:97–104. doi:10.1016/j.resuscitation.2015.09.396.
10. Arrich J, Holzer M, Havel C, Müllner M, Herkner H. Hypothermia for neuroprotection in adults after cardiopulmonary resuscitation. Cochrane Database Syst Rev. 2016;2(2):CD004128. doi:10.1002/14651858.CD004128.pub4.
11. Nielsen N, Wetterslev J, Cronberg T, Erlinge D, Gasche Y, Hassager C, Horn J, Hovdenes J, Kjaergaard J, Kuiper M, et al.

Targeted temperature management at 33 degrees C versus 36 degrees C after cardiac arrest. N Engl J Med. 2013;369(23):2197–206. doi:10.1056/NEJMoa1310519.

12. Worthington H, Pickett W, Morrison LJ, Scales DC, Zhan C, Lin S, Dorian P, Dainty KN, Ferguson ND, Brooks SC, et al. The impact of hospital experience with out-of-hospital cardiac arrest patients on post cardiac arrest care. Resuscitation. 2017;110:169–75. doi:10.1016/j.resuscitation.2016.08.032.
13. Brooks SC, Scales DC, Pinto R, Dainty KN, Racz EM, Gaudio M, Amaral ACKB, Gray SH, Friedrich JO, Chapman M, et al. The Postcardiac Arrest Consult Team: impact on hospital care processes for out-of-hospital cardiac arrest patients. Crit Care Med. 2016;44(11):2037–44. doi:10.1097/CCM.0000000000001863.
14. Stanger D, Kawano T, Malhi N, Grunau B, Tallon J, Wong GC, Christenson J, Fordyce CB. Door-to-targeted temperature management initiation time and outcomes in out-of-hospital cardiac arrest: insights from the continuous chest compressions trial. J Am Heart Assoc. 2019;8(9):e012001.
15. Kim KH, Shin SD, Song KJ, Ro YS, Kim YJ, Hong KJ, Jeong J, Park JH, Kim TH, Kong SY, et al. Cooling methods of targeted temperature management and neurological recovery after out-of-hospital cardiac arrest: a nationwide multicenter multi-level analysis. Resuscitation. 2018;125:56–65. doi:10.1016/j.resuscitation.2018.01.043.
16. Seder DB, Van der Kloot TE. Methods of cooling: practical aspects of therapeutic temperature management. Crit Care Med. 2009;37(7 Suppl):S211–S22. doi:10.1097/CCM.0b013e3181aa5bad.
17. Kim Y-M, Youn CS, Kim SH, Lee BK, Cho IS, Cho GC, Jeung KW, Oh SH, Choi SP, Shin JH, et al. Adverse events associated with poor neurological outcome during targeted temperature management and advanced critical care after out-of-hospital cardiac arrest. Crit Care. 2015;19(1):283. doi:10.1186/s13054-015-0991-9.
18. Kim F, Nichol G, Maynard C, Hallstrom A, Kudenchuk PJ, Rea T, Copass MK, Carlbom D, Deem S, Longstreth WT, et al. Effect of prehospital induction of mild hypothermia on survival and neurological status among adults with cardiac arrest: a randomized clinical trial. JAMA. 2014;311(1):45–52. doi:10.1001/jama.2013.282173.
19. Lees M, Elcock M. Safety of interhospital transport of cardiac patients and the need for medical escorts. Emerg Med Australas. 2008;20(1):23–31. doi:10.1111/j.1742-6723.2007.01020.x.
20. Jeyaraju M, Andhavarapu S, Palmer J, Bzhilyanskaya V, Friedman E, Lurie T, Patel P, Raffman A, Wang J, Tran QK, et al. Safety matters: a meta-analysis of interhospital transport adverse events in critically ill patients. Air Med J. 2021;40(5):350–8. doi:10.1016/j.amj.2021.04.008.
21. Witzel K. Effects of emergency ambulance transportation on heart rate, blood pressure, corticotropin, and cortisol. Ann Emerg Med. 1999;33(5):598–9. doi:10.1016/s0196-0644(99)70352-5.
22. Torre Monmany N, Maya Gallego S, Esclapés Giménez T, Sardà Sánchez M, Rodríguez Losada O, Martínez Planas A, Oller Fradera O, Alarcón A, Esteban E. Challenges in the application of non-servocontrolled therapeutic hypothermia during neonatal transport in Catalonia. An Pediatr (Engl Ed). 2021;95(6):459–66. doi:10.1016/j.anpede.2021.07.005.
23. Gupta N, Shipley L, Goel N, Browning Carmo K, Leslie A, Sharkey D. Neurocritical care of high-risk infants during inter-hospital transport. Acta Paediatr. 2019;108(11):1965–71. doi:10.1111/apa.14940.
24. NEDIS annual report. [accessed 2022 Jul 1]. https://www.e-gen.or.kr/nemc/statistics_annual_report.do?brdclscd=02.
25. Kim TH, Song KJ, Shin SD, Ro YS, Hong KJ, Park JH. Effect of specialized critical care transport unit on short-term mortality of critically ILL patients undergoing interhospital transport. Prehosp Emerg Care. 2020;24(1):46–54. doi:10.1080/10903127.2019.1607959.
26. Lee BK, Jeung KW, Jung YH, Lee DH, Lee SM, Cho YS, Heo T, Yun JG, Min YI. Relationship between timing of cooling and outcomes in adult comatose cardiac arrest patients treated with targeted temperature management. Resuscitation. 2017;113:135–41. doi:10.1016/j.resuscitation.2016.12.002.
27. Paal P, Brugger H, Strapazzon G. Accidental hypothermia. Handb Clin Neurol. 2018;157:547–63. doi:10.1016/B978-0-444-64074-1.00033-1.
28. Waydhas C. Intrahospital transport of critically ill patients. Crit Care. 1999;3(5):R83–9. doi:10.1186/cc362.
29. Haugk M, Sterz F, Grassberger M, Uray T, Kliegel A, Janata A, Richling N, Herkner H, Laggner AN. Feasibility and efficacy of a new non-invasive surface cooling device in post-resuscitation intensive care medicine. Resuscitation. 2007;75(1):76–81. doi:10.1016/j.resuscitation.2007.03.001.
30. Mayer SA, Kowalski RG, Presciutti M, Ostapkovich ND, McGann E, Fitzsimmons B-F, Yavagal DR, Du YE, Naidech AM, Janjua NA, et al. Clinical trial of a novel surface cooling system for fever control in neurocritical care patients. Crit Care Med. 2004;32(12):2508–15. doi:10.1097/01.ccm.0000147441.39670.37.
31. Perman SM, Elmer J, Maciel CB, Uzendu A, May T, Mumma BE, Bartos JA, Rodriguez AJ, Kurz MC, Panchal AR, et al. 2023 American Heart Association Focused Update on Adult Advanced Cardiovascular Life Support: an update to the American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2024;149(5):e254–73. doi:10.1161/CIR.0000000000001194.
32. Kim Y-M, Jeung KW, Kim WY, Park YS, Oh JS, You YH, Lee DH, Chae MK, Jeong YJ, Kim MC, et al. 2020 Korean guidelines for cardiopulmonary resuscitation. Part 5. Post-cardiac arrest care. Clin Exp Emerg Med. 2021;8(S):S41–S64. doi:10.15441/ceem.21.025.
33. Fanara B, Manzon C, Barbot O, Desmettre T, Capellier G. Recommendations for the intra-hospital transport of critically ill patients. Crit Care. 2010;14(3):R87. doi:10.1186/cc9018.
34. Wilcox SR, Wax RS, Meyer MT, Stocking JC, Baez AA, Cohen J, Moss MM, Frakes MA, Scruth EA, Weir WB, et al. Interfacility transport of critically ill patients. Crit Care Med. 2022;50(10):1461–76. doi:10.1097/CCM.0000000000005639.
35. Szakmar E, Kovacs K, Meder U, Nagy A, Szell A, Bundzsity B, Somogyvari Z, Szabo AJ, Szabo M, Jermendy A, et al. Feasibility and safety of controlled active hypothermia treatment during transport in neonates with hypoxic-ischemic encephalopathy. Pediatr Crit Care Med. 2017;18(12):1159–65. doi:10.1097/PCC.0000000000001339.