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Outcome and current status of therapeutic hypothermia after out-of-hospital cardiac arrest in Korea using data from the Korea Hypothermia Network registry

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Objective Therapeutic hypothermia (TH) has become the standard strategy for reducing brain damage in the postresuscitation period. The aim of this study was to investigate current TH performance and outcomes in out-of-hospital cardiac arrest (OHCA) survivors using data from the Korean Hypothermia Network (KORHN) registry.

Methods We used the KORHN registry, a web-based multicenter registry that includes 24 participating hospitals throughout the Republic of Korea. Adult comatose OHCA survivors treated with TH between 2007 and 2012 were included. The primary outcomes were neurological outcome at hospital discharge and in-hospital mortality. The secondary outcomes were TH performance and adverse events during TH.

Results A total of 930 patients were included, of whom 556 (59.8%) survived to discharge and 249 (26.8%) were discharged with good neurologic outcomes. The median time from return of spontaneous circulation (ROSC) to the start of TH was 101 minutes (interquartile range [IQR], 46 to 200 minutes). The induction, maintenance, and rewarming durations were 150 minutes (IQR, 80 to 267 minutes), 1,440 minutes (IQR, 1,290 to 1,440 minutes), and 708 minutes (IQR, 420 to 900 minutes), respectively. The time from the ROSC to coronary angiography was 1,045 hours (IQR, 121 to 12,051 hours). Hyperglycemia (46.3%) was the most frequent adverse event.

Conclusion More than one-quarter of the OHCA survivors (26.8%) were discharged with good neurologic outcomes. TH performance was appropriately managed in terms of the factors related to its timing, including cooling start time and rewarming duration.

Keywords Out-of-hospital cardiac arrest; Hypothermia, induced; Registries

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Capsule Summary

What is already known

The effectiveness of therapeutic hypothermia (TH) to the cardiac arrest survivors has been proven. Several studies reported the outcome and status of post-cardiac arrest care including TH of their own countries.

What is new in the current study

Of total 930 out-of-hospital cardiac arrest survivors treated with TH between 2007 and 2012, 59.8% survived to discharge and 26.8% were discharged with good neurological outcomes. This is the first report with large-scale multi-centered registries in Korea.

INTRODUCTION

Many cardiac arrest survivors remain comatose or die even after achieving return of spontaneous circulation (ROSC).[1] Therapeutic hypothermia (TH) prevents neurologic injury from mitochondrial damage, cellular membrane damage, intracellular acidosis, the formation of oxygen free radicals, and increased excitotoxicity after ischemia–reperfusion injury related to cardiac arrest.[2-5] The American Heart Association (AHA) recommends TH (target temperature, 32°C to 34°C; duration, 12 to 24 hours) as class I for out-of-hospital cardiac arrest (OHCA) survivors with ventricular fibrillation or pulseless ventricular tachycardia and class IIb for OHCA survivors with non-shockable rhythm or in-hospital cardiac arrest.[6] However, many TH-related issues have yet to be sufficiently resolved. The effectiveness of TH for in-hospital cardiac arrest survivors or cardiac arrest survivors with non-shockable rhythm as well as the optimal TH target temperature and duration have not yet been proven.[7-12]

The etiology of cardiac arrest, incidence of shockable rhythm, emergency medical system, policy of post-cardiac arrest care, and cardiac arrest outcomes differ among countries.[13-17] Therefore, we should identify the current TH status of OHCA survivors in Korea to suggest recommendations for TH suitable to our circumstances. The purpose of the present study was to investigate the current status of post-cardiac arrest care, including TH, and patients outcome using data from a multicenter registry in Korea.

METHODS

Patients and registry

The Korea Hypothermia Network (KORHN) managed a web-based retrospective registry of cases of OHCA treated with TH that aimed to improve post-cardiac arrest care quality and outcomes. Adult (≥18 years) comatose patients treated with TH between January 2007 and December 2012 were included. Cases of cardiac arrest from trauma or stroke or that occurred in the hospital were excluded. Each principal investigator of 24 participating hospitals reviewed the hospital records of OHCA survivors treated with TH and entered their baseline characteristics, comorbidities, prehospital cardiac arrest characteristics, respiratory and circulatory status after ROSC, circulatory support, neurological status and exam results, TH practice, incidence of complications, cerebral performance category scale at discharge, and mortality rates. Three clinical research associates monitored the data and helped qualify it by sending queries to the investigators. Finally, a data manager checked the data and decided whether to accept or revise it.

Data collection

Data of cardiac arrest, age, gender, comorbidities (coronary heart disease, congestive heart failure, stroke, hypertension, diabetes mellitus, lung disease, renal impairment, liver cirrhosis, and malignancy), witness of collapse, bystander cardiopulmonary resuscitation (CPR), first monitored rhythm (ventricular fibrillation, pulseless ventricular tachycardia, asystole, pulseless electrical activity, and unknown), etiology of cardiac arrest (cardiac, submersion, drug, asphyxia, exsanguination, and other non-cardiac diseases), coronary reperfusion and circulatory support (coronary angiography, percutaneous coronary intervention, coronary artery bypass graft, extracorporeal bypass, intra-aortic balloon pump, and continuous renal replacement therapy), time from ROSC to coronary angiography, time from collapse to ROSC, serum glucose after ROSC, Glasgow Coma Scale score after ROSC, time from ROSC to start of TH, time from start of TH to achieving the target temperature, maintenance duration, rewarming duration, target temperature, shock, TH method (blanket, ice bag, adhesive pad, garment, fan, linen, cold saline, intravascular catheter, lavage, and extracorporeal membrane oxygenation), core temperature monitoring site, complications (overcooling, bradycardia, hypokalemia, hyperglycemia, bleeding, hypotension, hyperthermia, hyperkalemia, hypoglycemia, seizure, pneumonia, and sepsis), and Cerebral Performance Category (CPC) score at discharge were collected.

The first monitored rhythm (collected by the emergency medical service or in the emergency department) was recorded. The time from collapse to ROSC was defined as the time from witness or detection of collapse to ROSC. Complications were defined as follows: overcooling (< 32°C), hyperthermia (≥ 38°C), bradycardia (< 40 beats/min), hypokalemia (≤ 3.0 mEq/L), hyperkalemia (≥ 5.0 mEq/L), hypoglycemia (< 80 mg/dL), hyperglycemia (≥ 180 mg/dL), hypotension (systolic blood pressure [SBP] < 90 mmHg, mean arterial pressure [MAP] < 60 mmHg for at least 30 minutes or the need for supportive measures to maintain a SBP > 90 mmHg or MAP > 60 mmHg), seizure (either clinically involuntary movement or epileptiform discharge on an electroencephalogram), or pneumonia (new or progressive consolidation on the chest radiograph, fever, leukocytosis, and the presence of purulent tracheobronchial secretions).

Primary and secondary outcomes

The primary outcomes were neurologic outcome and survival assessed using the CPC score at hospital discharge according to the recommendations for outcome assessment in comatose cardiac arrest survivors and recorded as CPC 1 (good performance), CPC 2 (moderate disability), CPC 3 (severe disability), CPC 4 (vegetative state), and CPC 5 (brain death or death).[18] Neurological outcome was dichotomized as either good (CPC 1 or 2) or poor (CPC 3–5). The secondary outcomes were practical TH status and its related complications.

Statistical analysis

Categorical variables are given as frequencies and percentages. Comparisons of categorical variables were performed using the χ^2 test or Fisher exact test as appropriate. Continuous variables are given as median values with interquartile ranges. The Mann-Whitney U-test was conducted to compare continuous variables. The Jonckheere-Terpstra test was used to analyze trends of non-normally distributed variables. Data were analyzed using PASW/SPSS ver. 18 (SPSS Inc., Chicago, IL, USA). Significance was set at values of $P < 0.05$.

RESULTS

Baseline characteristics

A total of 930 OHCA survivors were treated with TH, and the fill-up rate of data record entry of each case was 99.1% (IQR, 98.1% to 100%). The median number of registered case at each hospital was 26 (IQR, 11 to 51). The maximal and minimal registered numbers of case were 171 and 2, respectively. Six hospitals started offering TH prior to 2007, two since 2009, six since 2010, nine since 2011, and one since 2012. Fig. 1 shows the geographical distribution of the 24 participating hospitals. A total of 39, 49, 75, 117, 274, and 375 OHCA survivors were treated with TH yearly between 2007 and 2012.

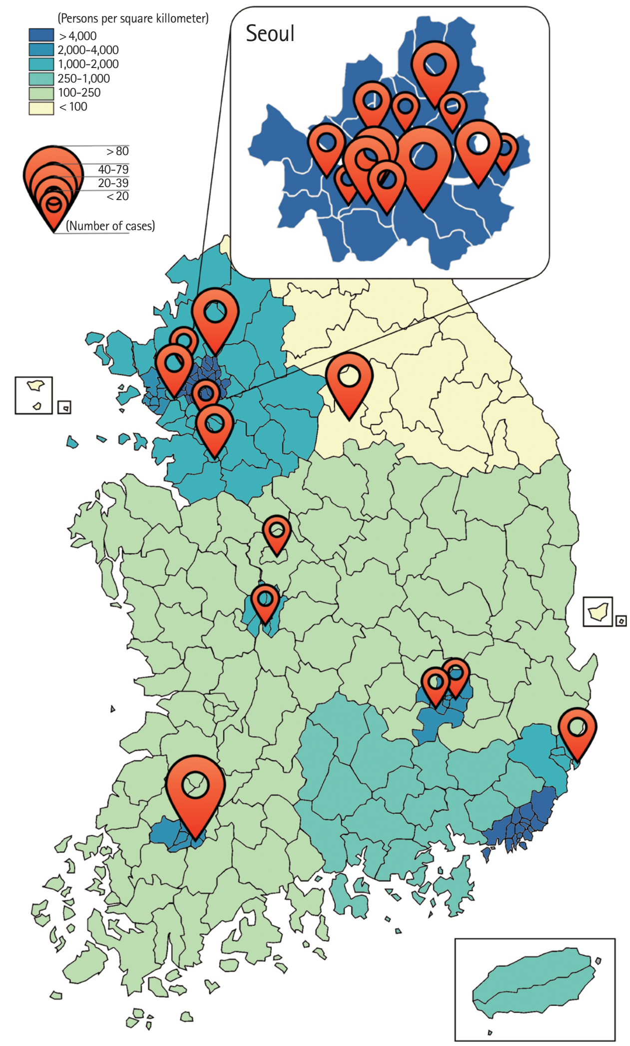

Fig. 1. Geographic distribution of the 24 participating hospitals.

The patients' clinical characteristics are shown in Table 1. The median age was 58 years (IQR, 46 to 70 years) and 650 patients (69.9%) were men. Patients with a good neurological outcome were significantly younger ($P < 0.001$) and more likely to be male ($P = 0.001$). Hypertension and diabetes mellitus were the most frequent comorbidities. Patients with stroke, hypertension, diabetes mellitus, lung disease, and renal impairment were more likely to have a poor neurological outcome. A total of 622 collapses (66.9%) were witnessed, while 281 OHCA survivors (30.2%) received bystander CPR. Shockable rhythms were delivered to 243 patients (26.1%), and non-shockable rhythms were delivered to 653 patients (70.2%). There were 564 cases (60.6%) of presumed cardiac etiology. A good neurological outcome was associated with witness of collapse, bystander CPR, shockable rhythm, and

Table 1. Demographic data of the patients and cardiac arrest events

Variable	Total (n = 930)	Good (n = 249)	Poor (n = 681)	P-value
Age (yr)	58 (46–70)	50 (40–60)	62 (49–72)	< 0.001
Male gender	650 (69.9)	194 (77.9)	456 (67.0)	0.001
Comorbidity				
Coronary heart disease	112 (12.0)	34 (13.7)	78 (11.5)	0.361
Congestive heart failure	29 (3.1)	5 (2.0)	24 (3.5)	0.239
Stroke	46 (4.9)	5 (2.0)	41 (6.0)	0.012
Hypertension	321 (34.5)	184 (73.9)	425 (62.4)	0.001
Diabetes mellitus	209 (22.5)	31 (12.4)	178 (26.1)	< 0.001
Lung disease	56 (6.0)	4 (1.6)	52 (7.6)	0.001
Renal impairment	58 (6.2)	4 (1.6)	54 (7.9)	< 0.001
Liver cirrhosis	12 (1.3)	1 (0.4)	11 (1.6)	0.198
Malignancy	27 (2.9)	5 (2.0)	22 (3.2)	0.326
Witness	622 (66.9), 928[a]	203 (81.5), 249[a]	419 (61.7), 679[a]	< 0.001
Bystander CPR	281 (30.2), 895[a]	100 (40.1), 235[a]	181 (26.6), 660[a]	< 0.001
First monitored rhythm				< 0.001
Vf/pulseless VT	243 (26.1)	147 (59.0)	96 (14.1)	
Pulseless electrical activity	172 (18.5)	40 (16.1)	132 (19.4)	
Asystole	481 (51.7)	47 (18.9)	434 (63.7)	
Unknown	34 (3.7)	15 (6.0)	19 (2.8)	
Etiology of cardiac arrest				< 0.001
Cardiac	564 (60.6)	221 (88.8)	343 (50.4)	
Submersion	27 (2.9)	1 (0.4)	26 (3.8)	
Drug	27 (2.9)	5 (2.0)	22 (3.2)	
Asphyxia	111 (11.9)	6 (2.4)	105 (15.4)	
Exsanguination	3 (0.3)	1 (0.4)	2 (0.3)	
Other non-cardiac	127 (13.7)	12 (4.8)	115 (16.9)	
Hanging	71 (7.6)	3 (1.2)	68 (10.0)	
Time from collapse to ROSC (min)	31 (22–42), 899[a]	25 (17–35), 245[a]	33 (25–45), 654[a]	< 0.001
Glucose after ROSC (mg/dL)	242 (172–313), 876[a]	227 (166–279), 239[a]	247 (176–328), 637[a]	0.002
GCS after ROSC	3 (3–3)	3 (3–5)	3 (3–3)	< 0.001

Values are presented as median (interquartile range) or number (%).
CPR, cardiopulmonary resuscitation; Vf, ventricular fibrillation; VT, ventricular tachycardia; ROSC, return of spontaneous circulation; GCS, Glasgow Coma Scale.
[a]Number of cases for analysis.

cardiac etiology (Table 1). Shorter time from collapse to ROSC and lower glucose after ROSC were associated with good neurological outcome (P < 0.001).

Neurological outcome and survival according to first monitored rhythm

Of the total 930 patients, 556 (59.8%) survived to discharge and 249 (26.8%) were discharged with good neurological outcomes. Of the 243 patients who had experienced OHCA with shockable rhythm, 202 (83.1%) survived to discharge and 147 (60.5%) were discharged with good neurological outcomes. Of the 653 patients with OHCA and non-shockable rhythm, 327 (50.1%) survived to discharge and 87 (13.3%) were discharged with good neurological outcomes. Fig. 2 shows the frequencies of neurological outcome and survival according to first monitored rhythm.

TH practice and complications

Table 2 shows the TH practice following ROSC. The median time from collapse to start of TH was 101 minutes (IQR, 46 to 200 minutes), and that of patients with a poor neurological outcome was significantly shorter (P = 0.036). The target temperature of 33°C was most frequent. The median time from TH start to achieving the target temperature was 150 minutes (IQR, 80 to 267 minutes) and was significantly shorter in patients with a poor neurological outcome (P < 0.001). The median rewarming duration was 708 minutes (IQR, 420 to 900 minutes). The time from ROSC to TH start tended to decline (P = 0.002) and the rewarming duration tended to increase (P < 0.001) over time (Table 3). The rectum was the most frequently (61.4%) monitored for core temperature, and dual sites were monitored in 84 patients (9.0%).

Table 4 shows the incidence of complications during TH. Hyperglycemia, hypotension, seizure, overcooling, sepsis, and hyperkalemia were significantly more frequent in patients with poor neuro-

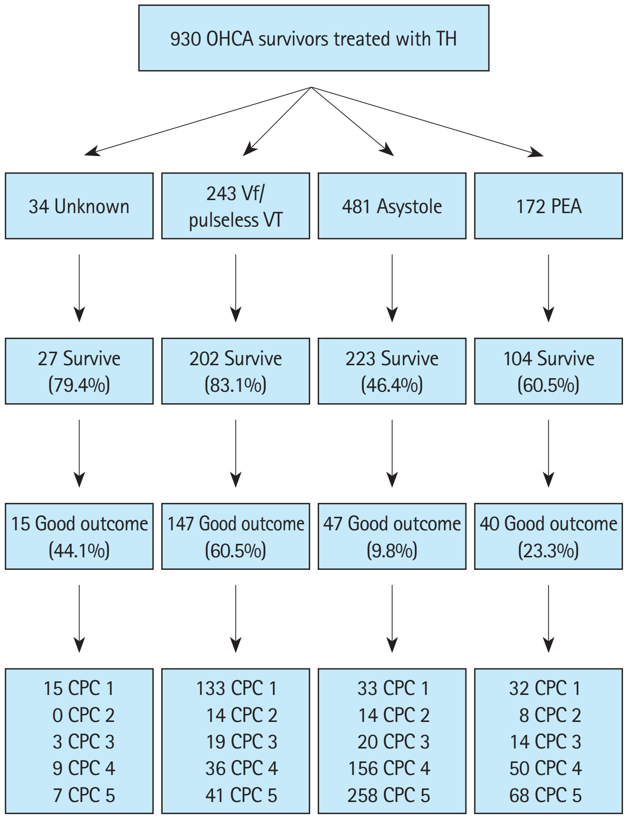

Fig. 2. Survival and neurological outcomes at discharge. Survival and neurological outcomes at discharge of the 930 patients with out-of-hospital cardiac arrests (OHCAs) treated with therapeutic hypothermia (TH) included in the study, divided into first monitored rhythm of ventricular fibrillation (Vf)/pulseless ventricular tachycardia (VT), asystole, pulseless electrical activity (PEA), and unknown. A good neurological outcome was defined as cerebral performance category (CPC) 1 or 2.

logical outcomes.

Cardiac care, circulatory supportive therapy, and TH methods

Table 5 shows the incidence of coronary reperfusion therapy and circulatory supportive therapies. Cardiogenic shock developed in 293 patients (31.5%). Coronary angiography was performed in 236 patients (25.4%), while percutaneous coronary intervention was performed in 86 patients (9.2%). The median time from ROSC to angiography was 1,045 hours (IQR, 121 to 12,051 hours) and tended to decline ($P < 0.001$) over time (Table 3).

Various TH methods were performed (Table 6). Several TH (external and internal cooling) methods were simultaneously used during the induction period and devices with feedback systems were used in 758 patients (81.5%). The manual passive rewarming method without a device was used in 39 patients (4.2%).

DISCUSSION

Of the total 930 registered OHCA survivors treated with TH, 556 (59.8%) survived to discharge and 249 (26.8%) were discharged with good neurological outcomes. The median time from ROSC to TH start was 101 minutes (IQR, 46 to 200 minutes), and the median rewarming duration was 708 minutes (IQR, 420 to 900 minutes). The time from ROSC to TH start decreased and rewarming duration increased annually. Coronary angiography was performed in 236 patients (25.4%); although the time to angiography decreased annually, it took longer to perform coronary angiography. The most frequent complications during TH were hyperglycemia,

Table 2. Therapeutic hypothermia characteristics

Characteristic	Total (n = 930)	Good (n = 249)	Poor (n = 681)	P-value
Time from ROSC to start of TH (min)	101 (46–200), 902[a]	115 (56–222), 245[a]	96 (43–190), 657[a]	0.036
Target temperature (°C)				0.256
32	8 (0.9)	1 (0.4)	7 (1.0)	
33	835 (89.8)	230 (92.4)	605 (88.8)	
34	84 (9.0)	18 (7.2)	66 (9.7)	
35	3 (0.3)	0 (0.0)	3 (0.4)	
Time from start of TH to achieve target temperature (min)	150 (80–267), 897[a]	195 (120–328), 244[a]	130 (61–240), 653[a]	< 0.001
Duration of maintenance (min)	1,440 (1,290–1,440), 828[a]	1,440 (1,320–1,440), 244[a]	1,440 (1,287–1,440), 584[a]	0.243
Duration of rewarming (min)	708 (420–900), 794[a]	660 (420–780), 246	720 (452–960), 548[a]	0.004
Monitor site of temperature				
Rectum	571 (61.4)			
Esophagus	223 (24.0)			
Bladder	157 (16.9)			
Tympanic membrane	36 (3.9)			
Axilla	21 (2.3)			

Values are presented as median (interquartile range) or number (%).
ROSC, return of spontaneous circulation; TH, therapeutic hypothermia.
[a]Number of cases for analysis.

Table 3. Performance of therapeutic hypothermia and coronary angiography after return of spontaneous circulation by year

Variable	2007 (n=39)	2008 (n=49)	2009 (n=75)	2010 (n=118)	2011 (n=274)	2012 (n=375)	P-value
Time from ROSC to TH (min)	108 (43–265)	168 (58–168)	112 (59–262)	111 (53–234)	97 (46–203)	92 (40–175)	0.002
Rewarming duration (min)	315 (150–600)	420 (305–848)	420 (300–638)	600 (360–780)	720 (505–900)	755 (608–1,020)	< 0.001
Time from ROSC to angiography (hr)	12,820 (924–37,200)	12,981 (107–20,687)	14,083 (8,345–25,715)	5,659 (232–13,361)	450 (103–7,494)	236 (106–9,736)	< 0.001

Values are presented as median (IQR).
ROSC, return of spontaneous circulation; TH, therapeutic hypothermia; IQR, interquartile range.

Table 4. Adverse events during therapeutic hypothermia

Variable	Total (n=930)	Good (n=249)	Poor (n=681)	P-value
Hyperglycemia	431 (46.5), 927	91 (36.5), 249	340 (50.1), 678	< 0.001
Pneumonia	345 (37.3), 924	80 (32.1), 249	265 (39.3), 675	0.047
Hypotension	335 (36.1), 927	62 (24.9), 249	273 (40.3), 678	< 0.001
Seizure	292 (31.8), 917	55 (22.3), 247	237 (35.4), 670	< 0.001
Hypokalemia	264 (28.5), 927	71 (28.5), 249	193 (28.5), 678	0.989
Overcooling	181 (19.5), 927	27 (10.8), 249	154 (22.7), 678	< 0.001
Sepsis	136 (14.7), 924	20 (8.1), 248	116 (17.2), 676	0.001
Bradycardia	123 (13.3), 927	36 (14.5), 249	87 (12.8), 678	0.518
Hyperthermia after rewarming	104 (12.4), 853	31 (12.6), 246	73 (12.0), 607	0.816
Hypoglycemia	85 (10.0), 851	25 (10.2), 246	60 (9.9), 851	0.914
Hyperkalemia	59 (6.9), 850	9 (3.7), 246	50 (8.3), 604	0.016
Bleeding	38 (4.1), 927	7 (2.8), 249	31 (4.6), 678	0.231

Values are presented as number (%), number of cases for analysis.

Table 5. Coronary reperfusion and other circulatory supportive therapies (n=930)

Variable	No. (%)
Coronary angiography	236 (41.8), 564[a)]
Coronary artery bypass graft	8 (1.4), 564[a)]
Intraaortic balloon pump	39 (4.2)
Exctracoporeal membrane oxygenation	34 (3.7)
Continuous renal replacement therapy	83 (8.9)

[a)]Number of cases for analysis.

Table 6. Therapeutic hypothermia methods

Variable	Induction	Maintenance	Rewarming
External cooling			
Blanket	344 (37.0)	320 (34.4)	295 (31.7)
Ice bag	348 (37.4)	93 (10.0)	26 (2.8)
Adhesive pad	193 (20.8)	193 (20.8)	176 (18.9)
Garment	78 (8.4)	73 (7.8)	65 (7.0)
Fan	62 (6.7)	8 (0.9)	3 (0.3)
Linen	42 (4.5)	0 (0.0)	12 (1.3)
Internal cooling			
Cold saline	636 (68.4)	73 (7.8)	21 (2.3)
Intravascular catheter	261 (28.1)	265 (28.5)	247 (26.6)
Lavage	74 (8.0)	33 (3.5)	0 (0.0)
Extracorporeal membrane oxygenation	15 (1.6)	15 (1.6)	10 (1.1)

Values are presented as number (%).

pneumonia, hypotension, seizure, and hypokalemia.

The two randomized controlled trials that proved the clinical effectiveness of TH enrolled only patients with OHCA and ventricular fibrillation.[19,20] Cardiac arrest survivors with a non-shockable rhythm had low proportion of good neurological outcomes and survival compared to patients with a shockable rhythm, and the AHA recommends class IIb TH in patients with OHCA and a non-shockable rhythm since its effectiveness in patients with OHCA and a non-shockable rhythm has not been proven.[6,8,21,22] Previous studies have analyzed the outcomes independent of the first monitored rhythm because the shockable rhythm was associated with good outcomes.[8,21,22] A study using a retrospective registry demonstrated that patients with OHCA and a shockable rhythm had a 56% chance of a good neurological outcome and a 61% chance of survival.[21] A study by Dumas et al.[8] reported that patients with OHCA and a shockable rhythm had a 44% chance of a good neurological outcome. A study by Soga et al.[22] also reported that patients with OHCA and a shockable rhythm had a 66% chance of good neurologic outcome at 30 days after cardiac arrest. The patients with OHCA and a shockable rhythm in the present study had a 60.5% chance of a good neurological outcome, similar to that observed in previous studies. Dumas et al.[8] reported that patients with OHCA and a non-shockable rhythm had a 15% chance of a good neurological outcome; the present study showed the same result (14.6%).

The optimal TH start time has not yet been identified. The Hypothermia after Cardiac Arrest (HACA) study group started TH within 105 minutes (IQR, 61 to 192 minutes) after ROSC.[20] In an animal study, the delayed start of TH attenuated its beneficial effect.[23] Therefore, an early TH start after ROSC is commonly accepted. Recent studies using a registry described TH start times after ROSC of 90 minutes (IQR, 60 to 165 minutes) and 57.5 minutes (IQR, 21 to 138 minutes), relatively earlier than that of the HACA study.[13,21,23] The TH start time in the present study was 101 minutes (IQR, 46 to 200 minutes). TH was thought to be performed more actively than before because it was started earlier; however, the TH start time was not associated with outcomes.[21] Since TH start time might not be a variable that influences clinical outcomes, other powerful factors must be considered.

Rapid induction to achieve the target temperature is recommended to avoid risks and side effects such as shivering and metabolic disorders.[24] The HACA study reported a median induction period of 8 hours (IQR, 4 to 16 hours).[20] However, recently reported studies using registry data demonstrated shorter induction periods of 260 minutes (IQR, 178 to 400 minutes) and 3.0 hours (IQR, 1.3 to 5.8 hours).[13,21] The median induction period in the present study was similar with those of previous studies using a registry.

The optimal maintenance period has not been identified either. The AHA currently recommends a maintenance period of 12–24 hours since the two randomized controlled trials, to date, maintained TH for 12 or 24 hours.[6,19,20] Several other studies have also reported a maintenance period of 12 to 24 hours.[10,25-27] A study using a registry performed in Japan reported a longer median maintenance period of 25 hours (IQR, 24 to 43 hours) and found no association between maintenance period and outcomes.[13] However, a well-controlled target temperature for >18 hours correlated with good neurological outcomes.[11] The quality of the maintenance period might be more critical than its duration.

Rewarming starts after completion of the maintenance period. Slow rewarming helps avoid side effects such as electrolyte imbalance, hypoglycemia, and hyperthermia.[24] The AHA has no detailed recommendation about the rewarming period, but several studies set a rewarming rate of 0.25°C/hr to 0.5°C/hr.[6,8,9,12] The median rewarming duration was 708 minutes (IQR, 420 to 900 minutes) in the present study and became adequate over time.

Coronary reperfusion therapy is one of the cornerstones of post-cardiac arrest care,[6] while the effectiveness of coronary angiography following ROSC is controversial. However, coronary angiography can be performed with TH in cardiac arrest survivors.[21,28] Coronary angiography was performed in 41.8% of cardiac etiologies in the present study. However, most uses were not performed as post-cardiac arrest care since the procedure is time-intensive, although the time required improved over time.

A study that included 765 OHCA survivors from 22 facilities demonstrated that pneumonia (48%), hyperglycemia (37%), and seizure (24%) were frequent complications and found that hyperglycemia and the use of antiepileptic drugs were associated with mortality.[29] A meta-analysis study that analyzed 63 clinical studies including cardiac arrest survivors treated with TH reported that hyperglycemia (52.4%), pneumonia (38.0%), and hypotension (20.8%) were frequent complications.[30] Hyperglycemia (46.3%), pneumonia (37.1%), hypotension (36.0%), seizure (31.4%), and hypokalemia (27.4%) were frequent complications in the present study. Hyperglycemia and pneumonia were the most frequent complications seen here, similar with previous studies, although the definition of complications differed among the studies.

Our study has several limitations. First, we cannot demonstrate the ratio of TH application, total OHCA survival rate, and TH effectiveness since the KORHN registry included only patients with OHCA who were treated with TH. Second, selection bias could not be avoided because most of the included facilities were teaching or university-affiliated hospitals located within the nation's capital region. Third, several data points were missing, which could affect the results, although the data manager and clinical research associates monitored the data and gave feedback to the principal investigators. Fourth, the KORHN registry was an emergency department-based registry, meaning that it could underestimate the number of patients transferred to a funeral home. This could be one of the reasons for the high survival rate reported here.

In summary, of the total 930 OHCA survivors, 59.8% survived to discharge and 26.8% were discharged with good neurological outcomes. The cooling start time and rewarming duration were appropriately managed according to current TH practice recommendations. Hyperglycemia and pneumonia were the most frequent complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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