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Clinical Paper

“Nobody is dead until warm and dead”: Prolonged resuscitation is warranted in arrested hypothermic victims also in remote areas – A retrospective study from northern Norway☆

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ABSTRACT

Hypothermic cardiac arrest has high mortality and few known prognostic factors. We studied retrospectively 34 victims of accidental hypothermia with cardiac arrest admitted to The University Hospital of North Norway during 1985–2013 who were resuscitated and rewarmed by extracorporeal circulation. No patient survived prior to 1999, while nine out of 24 (37.5%) survived hypothermic cardiac arrest from 1999 to 2013. The lowest measured core temperature among survivors was 13.7 °C; the longest time from cardiac arrest to return of spontaneous circulation was 6 h and 52 min. The only predictor of survival identified was lower blood potassium concentration in the nine survivors compared with the non-survivors. Submersion was not associated with reduced survival. Non-survivors consumed modest hospital resources. Most survivors had a favourable neurological outcome.

1. Introduction

Accidental hypothermia is defined as an unintentional drop in core body temperature below 35 °C. Hypothermic cardiac arrest is defined as cessation of circulation caused by hypothermia, including ventricular fibrillation (VF), ventricular tachycardia without pulse (VT), pulseless electric activity (PEA) and asystole (AS). Hypothermia is classified as mild (32–35 °C), moderate (28–32 °C), severe (20–28 °C) and profound (<20 °C).[1] These definitions represent respectively: a preserved capability to maintain core temperature through compensating thermoregulatory mechanisms (mild), loss of ability to sustain temperature voluntary and autonomic (moderate), high risk of malignant arrhythmias (severe) and cardiac arrest (profound).[2]

The clinical presentation of severe and profound accidental hypothermia is difficult to distinguish from clinical signs of death. The salvageable accidentally hypothermic patient could present without pulse, respiration and consciousness and with dilated non-reacting pupils and muscle rigidity. We have therefore advocated resuscitating and treating these patients aggressively regardless of clinical presentation, risking over-triage.

Hypothermia protects vital organs during ischaemia but can also lead to cardiac arrest, increased bleeding and may impede conventional resuscitation.[3–6] The combination of hypothermia with trauma is therefore especially dangerous.[7–10] Lifeless, hypothermic snow avalanche victims without air pocket have been found to have poor prognosis.[11,12] Excessive hyperkalaemia and asphyxia are other known predictors of death.[13–16]

Although mortality is high, the long-term outcome in most surviving hypothermic cardiac arrest patients is good with favourable neurological results and high quality of life, but some suffer neurological sequelae.[17–19]

Apart from consensus on using extracorporeal life support (ECLS) for rewarming,[20–22] details regarding the emergency treatment remain ambiguous.[5] An algorithm for in-hospital triage and treatment of hypothermic cardiac arrest patients, The Bernese Hypothermia Algorithm, have recently been suggested.[23] This algorithm focuses on the integration of trauma diagnostics with ECLS rewarming.

The University Hospital of North Norway, Tromsø (UNN Tromsø) is located in subarctic Norway at 69 °N latitude. The warmest month is July with a mean air temperature of 11.8 °C and mean sea

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temperature of 10.8 °C. The coldest month is January with a mean air temperature of −4.4 °C and mean sea temperature of 5.1 °C.[24] As a consequence of this all trauma patients in this region are at risk of hypothermia both summer and winter.[25] Cases of accidental cooling in water and snow combined with asphyxia are common due to the costal and pelagic fisheries and increasing outdoor activities with water and snow sports. Our hospital catchment area is large but sparsely populated, covering the northern part of Norway and Svalbard with about 500,000 inhabitants. The region has 12 smaller and larger emergency hospitals with cardiac surgery and extracorporeal circulation centralized to UNN Tromsø.

Our region has a well developed public Emergency Medical System (EMS) with a dense network of ground and sea ambulances staffed with professional paramedics working closely with decentralized doctors watch stations. Governmental air-ambulances with a total of four rotor-wing and six fixed-wing aircrafts are located at six different bases on 24/7/365 service. This EMS system has yielded excellent results in typical time-critical medical emergencies such as survival to discharge from out-of-hospital cardiac arrest and from acute myocardial infarctions despite long prehospital evacuation times.[26]

We have previously reported survival with good outcome from extreme accidental hypothermia with cardiac arrest and core temperature of 13.7 °C; and from long-lasting resuscitation with return of spontaneous circulation (ROSC) 6 h and 52 min after hypothermic cardiac arrest.[27,28]

We wanted to review treatment results in victims of accidental hypothermia and cardiac arrest over the last 28 years in our institution.

2. Methods

We identified all patients with accidental hypothermia and cardiac arrest admitted to UNN Tromsø and rewarmed with ECLS during the period 01.01.1985–15.06.2013.

Patients were found by searching our electronic patient record system for the ICD-10 codes hypothermia (T68), asphyxiation (T71), drowning and nonfatal submersion (T75.1) and other codes including avalanches and natural disasters. Data were matched with the hospitals database for extracorporeal circulation and the hospital ICU-database.

We analysed three time-periods: 1985–1991, 1992–1998 and 1999–2013. The first period was prior to moving to new university hospital buildings in 1991; the second represents the time until our first surviving victim of hypothermic cardiac arrest rewarmed with ECLS, and the third the period following this successful breakthrough case.

Death by asphyxia was defined as cardiac arrest following mechanical asphyxiation, snow avalanche burial without confirmed air pocket or drowning with no information on the use of life jacket, survival suit, or immersion before submersion. The hypothermic victims were divided into three groups: no asphyxia, snow avalanche burial or submersion. We defined the time from exposure to cardiac arrest as 0 min in avalanche victims if no air pockets were found. Likewise this time interval was set to 0 min in drowning victims when the patient story did not reveal immersion prior to submersion.

During the last time period studied, we have used patients hospital admission hyperkalaemia defined as $[K^+]_S > 12$ mMol L^{-1} as a guide to terminate further resuscitation or rewarming efforts.

Rewarming by extracorporeal circulation was performed using standard cardio-pulmonary bypass techniques with either peripheral femoral or central cannulation. During the rewarming, ECLS-flow was set to match the venous drainage at low temperatures, and at 34 °C nominal cardiac output was targeted. Veno-arterial temperature gradient was set to 10 °C initially. Final target temperature was between 34 and 37 °C depending on cardiopulmonary stability after rewarming. When extra-corporeal membrane oxygenator (ECMO) was used after rewarming, temperature was kept at 34 °C for 24–48 h.

Survival was defined as survival one year after the accident or at the end of the inclusion period.

Patients were scored using the 2005 Abbreviated Injury Score (AIS).[29] AIS scores were transformed to Injury Severity Score (ISS) as the sum of the square of the highest AIS scores in three different body regions.

The study was approved by the regional ethical committee (REK Nord) and the hospital management.

2.1. Statistics

Data were registered in Office-Excel®. Relevant data were analysed using SPSS (IBM SPSS statistics version 21). *p*-Values less than 0.01 were considered significant due to the relatively small number of cases and the high number of statistical comparisons performed. Results are given as median (minimum–maximum) unless otherwise stated.

Our material has relatively few patients and many variables, mostly not normally distributed. We analysed continuous data by nonparametric methods. Mann–Whitney *U* tests were used when comparing two groups, Kruskal Wallis tests when comparing three groups. Pairwise comparisons were performed by Mann–Whitney *U* tests when relevant. Chi square was used when testing nominal data. With a frequency less than 5 for any observation in 2 × 2 tables, we used Fisher's exact test. Rates of events were analysed by Poisson regression. Relevant data were analysed by logistic forward and backward likelihood regression analysis.

3. Results

3.1. Age, survival and temperature

Thirty-four patients were included in the study, 25 males (73.5%) and 9 females (26.5%). Nine patients survived (26.5%) while 25 died (73.5%). Their age was 27.5 years (2–73 years). First presenting core body temperature was 24.0 °C (8.9–32.9 °C). There was no difference in temperature between survivors and non-survivors ($p = 0.44$) (Table 1; Fig. 1).

Of the initial survivors, nine (90%) were alive one year following the accident.

Stepwise likelihood ratio logistic regression analysis showed initial serum potassium concentration to be the only predictor of survival (β for serum potassium = −0.54, standard error 0.26, $p = 0.04$, OR 0.58 (95% confidence interval 0.35–0.98), constant = 1.93. Nagelkerke's R square = 0.30).

Two surviving patients with less than one year observation time were alive at the end of the inclusion period 1 and 2 months post-resuscitation.

3.2. Neurological outcome

Six of nine survivors (66.7%) had minor neurological sequelae with Glasgow outcome scale (GOS) 5 (low disability), 2 (22.2%) had moderate disability with (GOS4) 4. One survivor (11.1%) had severe disability (GOS 3). One patient (4.0%) who survived almost to one year remained in a persistent vegetative state (GOS 2)[30] (Table 1).

3.3. Seasonal variance

Most patients were admitted during winter from October to May, peaking in January. Five patients (14.7%) were admitted

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Table 1
Characteristics of 34 patients with accidental hypothermic cardiac arrest rewarmed by ECLS at UNN Tromsø grouped by survival.

	Survival														*p*-value
	Non-survivors							Survivors							
	Count	Column N %	Minimum	25th percentile	Median	75th percentile	Maximum	Count	Column N %	Minimum	25th percentile	Median	75th percentile	Maximum	
Time period															
1985–1991	6	24.0%						0	0.0%						0.078
1992–1998	4	16.0%						0	0.0%						
1999–2013	15	60.0%						9	100.0%						
Gender															
Female	6	24.0%						3	33.3%						0.67*
Male	19	76.0%						6	66.7%						
Age, years			2.00	17.00	27.00	47.00	73.00		12.00	25.00	32.00	45.00	53.00	0.57	
Weight, kg			14	55	73	80	90		41	63	75	80	92	0.51	
Asphyxia type															
None	6	24.0%						3	33.3%						0.27*
Snow burial	6	24.0%						0	0.0%						
Submersion	13	52.0%						6	66.7%						
Cooling mechanism															
Air	4							1							0.16
	7							0							
Snow															
Water	14							8							
Season of admission															
Summer	4	16.0%						1	11.1%						0.723
	21	84.0%						8	88.9%						
Winter															
First measured temperature, °C			8.9	21.8	23.9	27.3	30.0		14.4	23.4	26.0	27.2	32.9	0.44	
Lowest measured temperature, °C			8.9	21.8	23.4	26.9	30.0		13.7	23.5	26.0	26.8	32.9	0.36	
Cooling rate, °C min^{-1}			.0	.0	.2	.3	3.0		.0	.2	.3	.4	1.4	0.29	
Trauma															
No additional mechanical trauma	22	88.0%						8	88.9%						1000*
Additional mechanical trauma	3	12.0%						1	11.1%						
ISS score			9.0	25.0	25.0	25.0	50.0		4.0	25.0	25.0	25.0	25.0	0.76	
Predicted mortality by ISS-score, %			2.0	9.0	9.0	9.0	75.0		0.0	9.0	9.0	9.0	26.0	0.91	
First heart rhythm after rescue															
Supraventricular rhythm > 60 min^{-1}	0							1							0.08
Bradycardia < 60 min^{-1}	1							1							
VT or VF	2							3							
Asystole	18							4							
PEA	4							0							
Prehospital defibrillation															
No defibrillation	12	92.3%						5	55.6%						0.116*
Defibrillation	1	7.7%						4	44.4%						
Distance from UNN Tromsø, km			1	50	140	203	423		1	44	102	170	203	0.42	
Time from exposure to cardiac arrest, min			0	0	0	60	780		0	0	25	45	480	0.68	
Time from exposure to asphyxia, min			0	0	0	30	60		0	0	5	25	40	0.78	
Time from accident to rescue, min			5	30	60	320	720		10	10	40	60	300	0.19	
Time from cardiac arrest to CPR, min			0	8	30	60	330		0	5	10	40	60	0.21	
CPR duration, min			15	108	148	185	470		3	85	107	184	274	0.26	
Time from cardiac arrest to ECLS or ROSC, min			15	145	208	270	465		3	95	165	194	292	0.15	

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Table 1 (*Continued*)

	Survival														*p*-value
	Non-survivors							Survivors							
	Count	Column N %	Minimum	25th percentile	Median	75th percentile	Maximum	Count	Column N %	Minimum	25th percentile	Median	75th percentile	Maximum	
Spontaneous circulation at hospital admission															
No spontaneous circulation	25	100.0%						7	77.8%						0.064*
Spontaneous circulation	0	0.0%						2	22.2%						
Time from ECLS to organized heart rhythm, min			0	15	25	45	85		0	0	20	37	60	0.44	
Rewarming rate, °C min^{-1}			2.5	3.9	5.5	7.5	12.9		1.9	3.6	5.3	7.4	10.1	0.68	
Target temperature after rewarming, °C			22.8	32.5	35.5	37.0	38.2		33.4	35.0	36.2	36.8	37.5	0.51	
Fluid balance per kg, mL kg^{-1}			13	62	94	143	325		20	41	67	88	273	0.18	
Diuresis during rewarming, mL h^{-1} kg^{-1}			0.00	0.00	0.01	0.07	0.28		0.01	0.02	0.04	0.11	0.22	0.08	
Ratio blood product to other fluids during rewarming			0.00	0.12	0.51	1.13	6.04		0.26	0.45	0.59	0.63	3.41	0.41	
pH			6.00	6.39	6.67	6.84	7.49		6.60	6.65	6.70	6.88	7.47	0.37	
PaO2, kPa			1.84	3.95	11.30	27.50	96.90		6.28	8.50	13.70	53.60	94.80	0.31	
PaCO2, kPa			2.12	7.97	10.40	16.25	31.20		2.79	7.62	8.36	14.10	17.60	0.59	
First measured serum sodium, mMol L^{-1}			0.0	134.0	137.5	145.5	175.0		126.0	131.0	136.0	150.0	171.0	0.92	
First measured serum potassium, mMol L^{-1}			2.3	4.8	6.5	8.7	17.0		2.4	3.6	4.3	5.0	5.9	0.01	
Highest measured serum potassium, mMol L^{-1}			3.2	5.1	7.7	10.1	17.3		3.9	4.6	5.2	5.9	8.2	0.11	
Serum TnT, mcg L^{-1}			10	232	1312	5470	51,310		10	2260	2308	4320	13,350	0.62	
Serum myoglobin, mcg L^{-1}			195	2769	4546	22,147	110,863		878	4204	10,200	15,330	17,789	1.00	
Serum CK-MB, mcg L^{-1}			16	45	78	877	1000		19	67	100	176	605	0.78	
Serum CK, mcg L^{-1}			652	1606	12,910	34,396	376,278		1352	2010	3672	20,105	73,909	0.64	
Serum ASAT, U L^{-1}			254	556	1257	2108	7617		106	156	452	1242	3324	0.08	
Serum ALAT, U L^{-1}			136	236	498	685	897		49	87	178	341	1475	0.03	
Intraoperative survival															
Declared dead in the OR	11	44.0%						0	0.0%						0.017*
Transferred to ICU for further therapy	14	56.0%						9	100.0%						
ECMO for post-rewarming cardiopulmonary insufficiency															
No ECMO	23	92.0%						5	55.6%						0.031*
ECMO	2	8.0%						4	44.4%						
Days on ECMO			1.0	1.0	1.0	1.0	1.0		3.0	3.0	4.0	5.5	6.0	0.13	
Days on ventilator			0.0	0.0	0.0	2.0	17.0		2.0	4.0	6.0	21.0	35.0	0.001	
Days in ICU			0.0	0.0	0.0	2.0	24.0		2.0	7.0	10.0	25.0	42.0	<0.001	
Days in hospital			0.0	0.0	0.4	2.0	218.0		10.0	14.0	39.0	60.0	106.0	<0.001	
Glasgow outcome scale at end of hospital stay															
1. Death	24	96.0%						0	0.0%						<0.001
2. Persistent vegetative state	1	4.0%						0	0.0%						
3. Severe disability	0	0.0%						1	11.1%						
4. Moderate disability	0	0.0%						2	22.2%						
5. Low disability	0	0.0%						6	66.7%						

All continuous data tested by Mann–Whitney *U*-test. All categorical data tested by Chi-square test. When the count in any cell during test for categorical data in a 2 × 2 table was less than 5.
[*] Fisher Exact test was used instead of Chi-square test.

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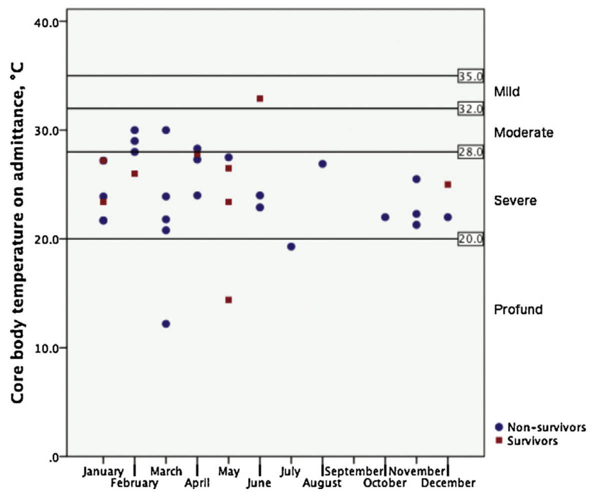

Fig. 1. Distribution of core temperature by month of admission in 34 patients with accidental hypothermic cardiac arrest admitted to the University Hospital of North Norway (UNN Tromsø) in the period 1985–2013.

during summer from June to September. There was no difference in probability of survival in summer or winter ($p = 0.72$) (Table 1).

Core body temperature did not differ on hospital admittance, nor the lowest measured core temperature in patients admitted during summer and during winter ($p = 0.93$ and 0.81) (Fig. 1).

3.4. Cooling mechanism

There was no difference in survival depending on the cooling mechanism ($p = 0.16$) (Table 1).

We found no difference in core temperature at admission among patients cooled by snow 28.0 °C (23.9–30.0 °C), by air 22.0 °C (8.9–30.0 °C) or by water 23.7 °C (14.4–32.9 °C) ($p = 0.04$) (Fig. 2). Eight of the nine patients cooled by snow were avalanche victims (88.9%), and none of these patients survived. Among the survivors, 8 were cooled by water (88.9%), one by air (11.1%).

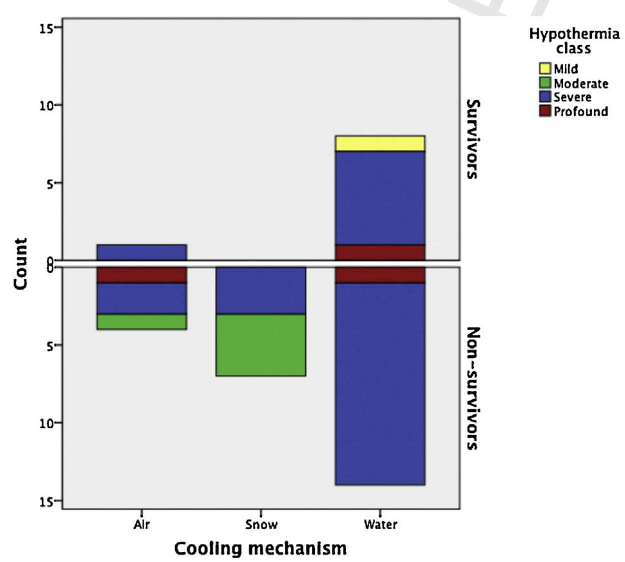

Fig. 2. Cooling mechanism and hypothermia classes in 34 patients with accidental hypothermic cardiac arrest admitted to the University Hospital of North Norway (UNN Tromsø) in the period 1985–2013.

3.5. Asphyxia

Six patients (17.6%) suffered asphyxia from snow avalanche burial. Nineteen patients (55.9%) were submerged in water during the course of the accident. Six of the 25 asphyxiated patients (24%) survived, three of the nine patients (33.3%) without asphyxia survived ($p = 0.67$). Six of 19 submerged patients (31.6%) survived while none of the six snow avalanche buried victims without confirmed air pocket at the time of excavation, survived ($p = 0.27$).

Median time from cardiac arrest to CPR was 75 minutes (min) (30–300 min) in the snow avalanche group, 25 min (5–90 min) in the submersion group and 0 min (0–150 min) in the group without asphyxia ($p = 0.004$).

The non-asphyxiated, snow burial and submerged hypothermic patients differed significantly in a number of variables.

3.6. Exposure to water

Median exposure time in water in survivors was 32.5 min (10–90 min) and 35 min (5–570 min) in non-survivors ($p = 0.40$). In submerged victims, median water temperature was 2.3 °C (0–9.4 °C) in survivors, while in non-survivors the water temperature was 4.8 °C (0–12.7 °C) ($p = 0.23$). Five out of 12 patients (41.7%) survived after being submerged in water with an estimated temperature below 6.0 °C, while one of seven patients (14.3%) submerged in water warmer than this, survived ($p = 0.33$). There were no differences in first measured core temperature in patients cooled by water below and above 6.0 °C ($p = 0.62$). Logistic regression analysis of survival in the submerged patients revealed no significant predictors of survival.

3.7. Trauma

With ISS-scores, hypothermia was among the three highest sub-scores for all patients. Four of 34 patients (11.8%) suffered significant additional mechanical trauma by ISS-score, one of the four survived ($p = 0.76$).

3.8. Heart rhythm

First recorded ECG-rhythm did not differ between survivors and non-survivors ($p = 0.08$). Asystole was present in 22 patients (64.7%), five had VT or VF (14.7%), four had PEA (11.8%), two bradycardia of HR < 60 bpm (5.9%), while one had sinus rhythm with HR > 60 (2.9%). In eight of 34 patients (23.5%) cardiac arrest was witnessed. Witnessed cardiac arrest did not affect survival ($p = 0.17$). Two patients admitted to hospital with a perfusing rhythm had cardiac arrest shortly after.

3.9. Prehospital care and evacuation

Survival did not increase with shorter duration of cardiac arrest, duration of CPR or time to ECLS (Table 1).

In all cases, victims had been rescued by local lay people or medical personnel. BLS and CPR as needed were started before evacuation to hospital.

One patient was stabilized at a local hospital, without delaying evacuation to UNN Tromsø. All other patients were transported directly primarily by the public air-ambulance system (Fig. 3).

Survivors and non-survivors did not differ in prehospital distance from accident site to UNN Tromsø (Table 1).

3.10. Blood chemistry

No patients with serum potassium concentration $[K^+]_s > 12\ \text{mMol L}^{-1}$ survived. Survivors had significantly lower

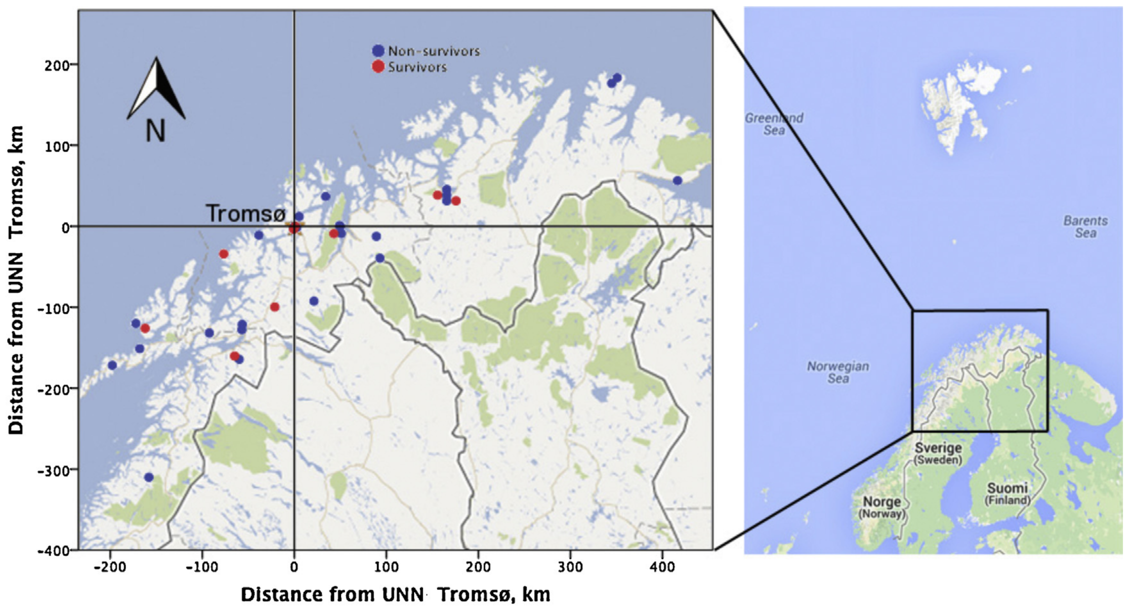

Fig. 3. Distance between scene of accident and Tromsø (at 0,0) in 34 patients with accidental hypothermic cardiac arrest admitted to the University Hospital of North Norway (UNN Tromsø) during 1985–2013.

$[K^+]_S$ on admission than non-survivors ($p = 0.01$). The highest $[K^+]_S$ among survivors was 5.9 mMol L^{-1}. In seven of the survivors (77.8%) and eight of the non-survivors (32%), $[K^+]_S$ was below 5.0 mMol L^{-1} ($p = 0.05$). (Fig. 4)

There was no difference in blood analyses for serum levels of ALAT, ASAT, and CK in survivors and non-survivors (Table 1).

3.11. Rewarming

Rewarming was done on cardiopulmonary bypass (CPB) except for one adult and four children rewarmed with ECMO.

There was no difference in rewarming rate or core body temperature on weaning between survivors and non-survivors (Table 1).

3.12. Survival and consumption of hospital resources

Median stay in ICU was 10 days (2–40 days) for survivors, 0 days (0–24 days) for non-survivors ($p < 0.001$). Median total hospital stay for survivors was 39 days (10–106 days), for non-survivors 0.35 days (0–218 days) ($p < 0.001$). Two non-survivors (5.9%) were accepted as organ donors. Median time on ventilator was 6 days (2–35 days) for survivors and 0 days (0–17 days) for non-survivors ($p = 0.001$) (Table 1; Fig. 5).

Six patients, three adults and three children, were treated with ECMO for cardiopulmonary insufficiency following extracorporeal rewarming. Four of the six patients survived. Median age was 21 years (3–53 years). Median duration of ECMO-treatment was 4 days (3–6 days) for survivors and 1 day (1–1 day) for non-survivors

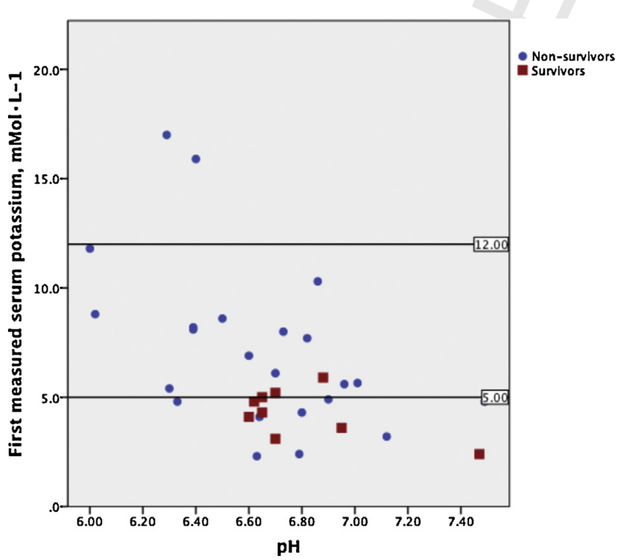

Fig. 4. Distribution of pH and serum potassium concentrations between 34 survivors and non-survivors with accidental hypothermic cardiac arrest admitted to the University Hospital of North Norway (UNN Tromsø) during 1985–2013.

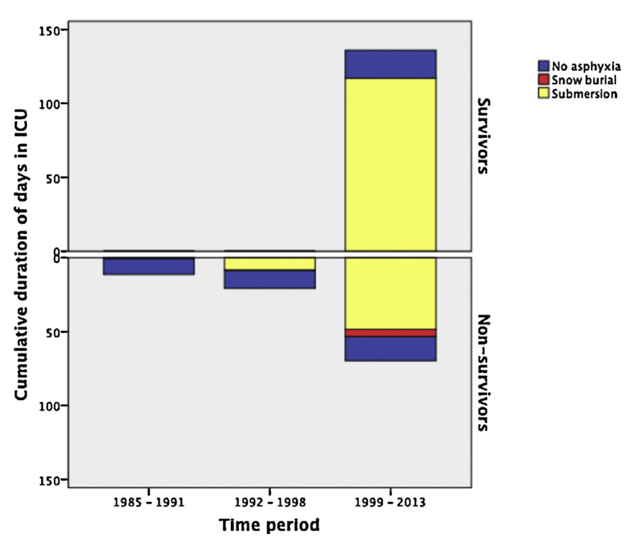

Fig. 5. Cumulative duration of ICU-stay among 34 victims of accidental hypothermic cardiac arrest admitted to the University Hospital of North Norway (UNN Tromsø) during 1985–2013. In total, non-survivors consumed less ICU-days than survivors ($p < 0.001$).

($p = 0.13$) (Table 1). The need for ECMO-treatment post-rewarming did not influence survival ($p = 0.16$).

No patient survived accidental hypothermia with cardiac arrest during the first two time periods, while nine out of 24 patients (37.5%) survived resuscitation from hypothermic cardiac arrest from 1999 to 2013.

4. Discussion

From 1985 to 2013, we saw an increased number of patients admitted in hypothermic cardiac arrest to our hospital. All surviving victims followed a successful case in 1999. We have experienced a change in professional attitudes towards this patient group among prehospital as well as hospital emergency teams. Health professionals as well as lay people and first responders were educated on the potential good survival in hypothermic cardiac arrest victims. We also published success stories of extreme survival. Such factors may have caused more cases of prolonged resuscitation with evacuation of lifeless victims with hypothermia directly to UNN Tromsø.

We found a high ratio of victims cooled by water and snow compared to previous studies. This explains a higher ratio of patients with primary asphyxia.

Asphyxiation, low initial arterial oxygen tension and indoor cooling were found to be negative predictors of survival in previous Norwegian studies of victims of accidental hypothermia.[13,14] This is in agreement with similar studies conducted in Austria, Canada, Great Britain, The Netherlands and Switzerland.[15,22,31–34]

The three groups of hypothermic victims (no asphyxia, snow burial or submersion) differed in several logistic and physiological variables without influencing survival. This may indicate that the type of accident and clinical presentation are not useful criteria when deciding to continue or stop active resuscitation and rewarming in this patient group.

Several of the submerged patients were cooled by very cold water at a higher cooling rate which is believed to be beneficial for survival.[35] We speculate that aspiration of cold water may induce rapid protective cerebral hypothermia without parallel decrease in core temperature, and thus give higher survival rates in drowned patients compared to other causes of asphyxia even at similar core temperatures.[36]

Our results support the use of $[K^+]_s > 12\ \text{mMol}\ L^{-1}$ on admission as a robust negative prognostic factor when deciding to terminate further resuscitation efforts.

Our hospital treatment of these patients was not directed by strict written algorithms, rather by consensus in limited teams of anaesthesiologist, perfusionist and surgeons based on clinical experiences and experimental research.[37,38] Our current clinical practice is close to the Bernese hypothermia algoritm,[23] and we have recently implemented formal regional guidelines for resuscitation and rewarming of accidental hypothermia victims in northern Norway and Svalbard.[39]

Rewarming with ECMO may give better prognosis.[22] Our data show that a need for ECMO-support post-rewarming did not influence survival. Using ECMO during the cardiopulmonary instability typically occurring post-rewarming may be more beneficial than large IV-volumes and inotropic pharmacological support.

The current AIS-system has no scoring of cardiac arrest related to hypothermia, thus ISS will not discriminate between hypothermia patients with and without circulation. With ISS, the predicted median mortality would be 9% (0–75%), while observed overall mortality rate was 73.5%. The current AIS-scoring system is not suitable to grade hypothermia as an isolated trauma.

Most non-survivors died within days if they survived rewarming with ECLS, while survivors had longer total hospital stays.

Nine patients with hypothermic cardiac arrest survived with vigorous resuscitation and hospital treatment. Eight of these made good recovery, while one survivor suffered severe neurological impairment. This compares well with findings in the Swiss study with extended follow-up time.[17]

Our aggressive resuscitation strategy is justified by a high proportion of survivors with good results from an otherwise lethal condition, while using limited hospital resources on non-survivors.

5. Limitations

The low number of patients in this study increase the risk of type 1 and type 2 statistical errors. Since we could not determine core temperatures at, or the exact moment of cardiac arrest in these patients, the absolute contributions of hypothermia versus asphyxia remain elusive.

Due to the dramatic nature of such accidents, exact prehospital time-factors, initial clinical presentation and other elements in often long chains of survival may be inaccurate.

6. Conclusion

Prehospital rescuers and hospital emergency teams cannot be sure which victim of hypothermic cardiac arrest will survive resuscitation attempts. Our experiences support starting immediate basic and advanced life support which must continue with maximum efforts until reaching a hospital with extracorporeal rewarming preparedness and clinical experience. The total extra expenditures on non-survivors are modest, and survivor's outcomes are favourable.

A continuous, strong chain of survival is crucial. The chain can be strengthened by informing and training the public, the prehospital professionals and hospital teams in clear consensus- and evidence-based guidelines. With few patients, further studies and international registers are needed to expand our knowledge of prognostic factors and rational treatment guidelines.[40]

We thus uphold our credo during the last 28 years: "No victim of accidental hypothermia is dead until warm and dead".

Conflict of interest statement

None.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2014.04.029.

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