

Comparison of intravascular and conventional hypothermia after cardiac arrest

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Abstract

Background: Therapeutic hypothermia is currently the best-documented method of improving neurological outcomes in patients after cardiac arrest and successful resuscitation. There is a variety of methods for lowering body temperature. However, there are no data showing that any specific method of cooling improves the results or increases survival. A simple method involving surface cooling and ice-cold intravenous fluids, as well as more technologically advanced methods, are used in clinical practice. One of the more advanced methods is intravascular hypothermia, during which cooling is carried out with the use of a special catheter located in the central vein.

Aim: To compare cooling with the use of intravascular hypothermia and cooling using the traditional method.

Methods: A prospective study was performed in 41 patients with acute coronary syndromes who did not regain consciousness after out-of-hospital or in-hospital cardiac arrest and restoration of spontaneous circulation. Therapeutic hypothermia (32–34°C) was obtained with the use of an intravascular method (group A, n = 20) or a traditional method (group B, n = 21) for a period of 24 hours. Intravascular cooling involved the use of a catheter inserted in the femoral vein connected to a heat exchanger (Alsius Coolgard, Zoll, Chelmsford, MA, USA). Traditional cooling was carried out using uncontrolled surface cooling, ice-cold intravenous fluids and ice-cold gastric lavage. Nasopharyngeal and urinary bladder temperatures were recorded hourly. The main analysed temperature was the urinary bladder temperature, as the heat exchanger in the intravascular hypothermia group was controlled by the readings taken from this site. Temperature profiles were compared.

Results: Temperature < 34°C was reached in 19 (95.0%) patients in group A and in 11 (52.4%) patients in group B (p = 0.004). Stable temperature profile (temperature in the range 32–34°C during the final 12 h of cooling) was reached in 16 (80%) patients in group A and in three (14.3%) patients in group B (p < 0.001). Periods of inadequate cooling (temperature > 34°C) and temperature overshoots (temperature < 32°C) were significantly more frequent in group B. Temperature profiles were significantly different in both groups in the readings taken from both sites.

Conclusions: The presented technique of intravascular hypothermia provides more precise temperature control in comparison with the traditional method.

Key words: hypothermia, cardiac arrest, cooling

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INTRODUCTION

The final outcome of patients after cardiac arrest (CA) and successful resuscitation who reach cardiac and general intensive care units is often very poor, resulting in either death or permanent neurological damage [1–3]. Therapeutic hypother-

mia is currently the best-documented method of improving outcome in this group of patients [1, 4] and according to the 2005 and 2010 European Resuscitation Council guidelines it is regarded as one of the key elements of post-resuscitation care in patients following out-of-hospital CA and ventricular

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fibrillation [5, 6]. The benefits of hypothermia have been confirmed by many authors [7–11].

Cooling should start as soon as spontaneous heart rhythm has been restored, aiming to achieve and maintain a temperature of between 32°C and 34°C. The cooling can be performed using cooling blankets and mattresses, ice bags, intravenous infusions of ice-cold crystalloid solutions and gastric lavage [6]. More technologically advanced methods are becoming increasingly popular. One of these methods is intravascular hypothermia, where the cooling is performed via a catheter located in the lumen of the femoral vein [12].

The first application of therapeutic intravascular hypothermia in Poland took place in 2004 in the Intensive Care Unit (ICU) of the Upper Silesian Medical Centre in Katowice, in a 52 year-old patient with acute myocardial infarction after out-of-hospital CA due to ventricular fibrillation. Our first case series was presented in 2005 [13].

There is a variety of methods for lowering body temperature, but there are no data showing that any specific method of cooling improves the results or increases survival. The aim of our study was to compare cooling with intravascular hypothermia and the conventional method (including uncontrolled surface cooling, ice-cold intravenous fluids and ice-cold gastric lavage).

METHODS

Study design

This prospective study was performed in 41 patients with an acute coronary syndrome who did not regain consciousness after out-of-hospital or in-hospital CA and restoration of spontaneous circulation. Therapeutic hypothermia was used in all patients. We aimed at obtaining a target temperature of 32–34°C as soon as possible and maintaining it within a stable range for a period of 24 h after the start of cooling. Patients were then re-warmed to 36.6°C, with the desired re-warming rate of 0.25°C/h. The observation period lasted 36 h and began with the start of cooling by a chosen method.

Hypothermia was obtained using either intravascular method (group A, $n = 20$) with the use of an intravascular catheter inserted in the femoral vein and a heat exchanger (Alsius Coolgard, Zoll, Chelmsford, MA, USA) or conventional method (group B, $n = 21$) with the use of uncontrolled surface cooling, ice-cold intravenous fluids and ice-cold gastric lavage.

The allocation of patients to study groups was non-randomised, depending on the equipment availability and physicians' preferences. The research protocol was approved by the Ethics Committee of the Medical University of Silesia.

Exclusions

Those excluded were: patients aged under 30 and over 75 years; with a total time of CA and resuscitation shorter than 5 min or longer than 60 min; with a time from CA to the first resuscitation attempt exceeding 15 min; with a time from resto-

ration of spontaneous circulation to the start of cooling exceeding 6 h; having a body temperature lower than 35°C before cooling; or having a score of 9 points or more according to the Glasgow Coma Scale before cooling.

Intensive Care Unit management

In all the patients, CA and post-CA management was conducted with the standard BLS (Basic Life Support) and ALS (Advanced Life Support) treatment regimens, in compliance with the European Resuscitation Council guidelines [5]. After restoring spontaneous circulation and revascularisation in the catheterisation laboratory (if appropriate), further treatment was primarily targeted at the protection of the central nervous system. It involved forced diuresis and maintaining: therapeutic hypothermia (core temperature 32–34°C for 24 h after the start of cooling), satisfactory gas exchange via mechanical ventilation, stable haemodynamics through appropriately selected inotropic agents, and normoglycaemia through continuous insulin infusion.

The treatment took place in the ICU and was performed by specialists in anaesthesiology and intensive care, in close co-operation with cardiologists. Routine therapeutic procedures with mechanical ventilation and pharmacotherapy were conducted in both treatment groups.

Protocol of therapeutic hypothermia

In the intravascular hypothermia group (group A), the cooling was provided via a catheter inserted in the femoral vein. The surface of the catheter was cooled by a fluid circulating within the catheter in a closed circuit. The system is automatically controlled by the patient's core body temperature, thereby allowing for precise temperature management. Cooling rate was programmed at 0.8°C/h (option "MAX" on the heat exchanger console) until reaching the temperature of 33°C, which was then automatically maintained; for 24 h after the start of cooling, after which re-warming was commenced at the rate of 0.25°C/h. No surface cooling or antipyretic drugs were used in this group during the 24-h hypothermia period.

In the conventional hypothermia group (group B), the following procedures were used: (1) rapid infusion of 30 mL/kg of ice-cold crystalloid solutions (1:1 Ringer solution and 0.9% NaCl, temperature 4°C, in 60 min), (2) wraps with ice-cold gel packs, changed every hour (particular attention paid to the head and the area along the course of large vessels), (3) initial intravenous injections of 1 g paracetamol, followed by an intravenous injection of 1 g metamizol after 6 h of cooling (further injections were repeated every 12 h, which resulted in alternating administration of both drugs every 6 h for the entire period of observation — independently of temperature) and (4) gastric lavage with ice-cold crystalloid solutions containing 1:1 Ringer solution and 0.9% NaCl. Practically, 250 mL of cold fluid was administered through a nasogastric tube (injection — 5 min, clamp — 25 min, passive

Table 1. Demographic data, medical status and body temperature directly before the start of cooling

	Group A — intravascular hypothermia (n = 20)	Group B — traditional hypothermia (n = 21)	P
Age [years]	59 ± 11	62 ± 9	0.28
Female gender	3 (15%)	4 (19%)	0.94
Body mass index	28.2 ± 5.4	27.1 ± 3.4	0.91
Cardiac arrest:			
Out of hospital	15 (75%)	18 (86%)	0.58
In hospital	5 (25%)	3 (14%)	
Glasgow Coma Scale	4.2 ± 1.4	4.9 ± 1.6	0.13
Heart rate [bpm]	102 ± 17	103 ± 19	0.94
Systolic arterial pressure [mm Hg]	132 ± 19	133 ± 31	0.91
Diastolic arterial pressure [mm Hg]	80 ± 8	80 ± 18	0.68
Central venous pressure [mm Hg]	14 ± 9	14 ± 4	0.57
Oxygen saturation [%]	98 ± 3	97 ± 6	0.85
Arterial blood gas analysis:			
pH	7.31 ± 0.09	7.34 ± 0.10	0.07
PaO ₂ [mm Hg]	163 ± 79	176 ± 116	0.93
PaCO ₂ [mm Hg]	40 ± 13	38 ± 7	0.91
Urinary bladder temperature [°C]	36.0 ± 1.3	35.9 ± 1.4	0.69
Nasopharyngeal temperature [°C]	36.0 ± 1.2	35.8 ± 1.4	0.82

backflow for 30 min). This cycle lasting 60 min was repeated every 3 h (unless the temperature dropped below 33°C or it was possible to maintain the temperature without gastric lavage). On completion of the 24-h cooling period, spontaneous re-warming took place.

Patient demographics and mean baseline body temperature did not differ significantly between the study groups (Table 1). Of the 41 enrolled patients, 25 (61%) were cooled in the Upper Silesian Medical Centre in Katowice, and 16 (39%) in the Silesian Centre for Heart Diseases in Zabrze.

Core temperature was measured in all patients using a nasopharyngeal probe (nasopharyngeal temperature) and a urinary bladder catheter (urinary bladder temperature). All temperatures were measured continuously and recorded hourly for the purpose of the study. It was assumed that a stable temperature profile comprised maintenance of urinary bladder temperature of 32–34°C in the final 12 h of a cooling period.

Statistical analysis

Temperature profiles were compared using analysis of variance for repeated measurements. The percentages of patients who achieved target temperature and maintained stable temperature profile were compared using the χ^2 test. The main analysed temperature was the urinary bladder temperature as the heat exchanger in the intravascular hypothermia group was controlled entirely by the readings taken from this site. A p value < 0.05 was considered significant.

RESULTS

During the whole period of cooling, urinary bladder temperature < 34°C was reached in 19 (95.0%) patients from group A and in 11 (52.4%) patients from group B (p = 0.004). The mean time to achieve temperature < 34°C was 6.3 ± 4.3 h in group A and 4.0 ± 3.2 h in group B (NS).

Stable temperature profile during hypothermia (maintenance of a urinary bladder temperature in a range of 32–34°C during the whole final 12 h of the cooling period) was reached in 16 (80%) patients from group A, but in only three (14.3%) patients from group B (p < 0.001). During the total 24 h of cooling, the urinary bladder temperature was kept in a desired range (32–34°C) for a mean period of 10.3 ± 3.5 h in group A and 3.0 ± 4.1 h in group B (p < 0.001) — overall for 85% and 25% (p < 0.001) of the cumulative cooling period calculated for all patients, respectively.

Periods of inadequate cooling (expressed by any reading of temperature above 34°C during the final 12 h of cooling) occurred in six (30%) patients from group A and in 15 (71.4%) patients from group B (p = 0.013). During the total 24 h of cooling, urinary bladder temperature was found to be above 34°C for a mean period of 1.8 ± 3.5 h in group A and 7.8 ± 5.4 h in group B (p < 0.001) — overall for 15% and 65% (p < 0.001) of the cumulative cooling period for all patients, respectively.

Periods of temperature overshoot (expressed by any reading of urinary bladder temperature below 32°C in the final 12 h of cooling) did not occur in group A, and occurred in

four (19.1%) patients from group B (NS). During the total 24 h of cooling, temperature was found to be below 32°C for a mean period of 1.2 ± 2.6 h in group B — overall for 10% of the cumulative cooling period for all patients in this group.

Percentages of patients who maintained a stable urinary bladder temperature profile and had periods of inadequate cooling or temperature overshoots in both study groups are shown graphically in Figure 1. Urinary bladder temperature profiles varied significantly between the groups (Fig. 2) — the same was also true for nasopharyngeal temperature (Fig. 3). A plot of urinary bladder temperatures for all studied patients (separately for groups A and B) is shown in Figure 4.

DISCUSSION

The results of our study indicate that the parameters of cooling obtained using intravascular hypothermia were significantly better than those obtained using the conventional method.

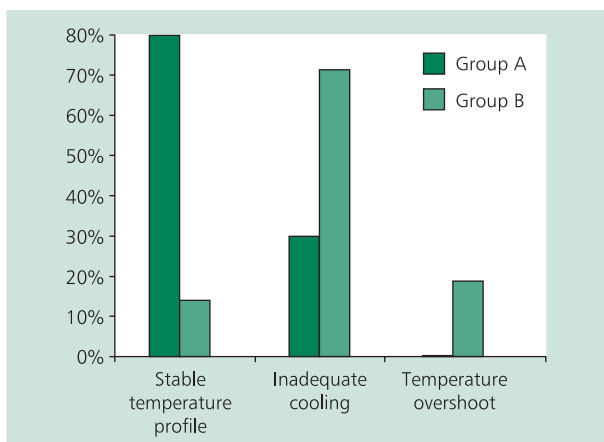


Figure 1. Percentage of patients with stable urinary bladder temperature profile, inadequate cooling and temperature overshoots in both groups (group A — intravascular hypothermia, group B — traditional hypothermia). All differences are highly statistically significant

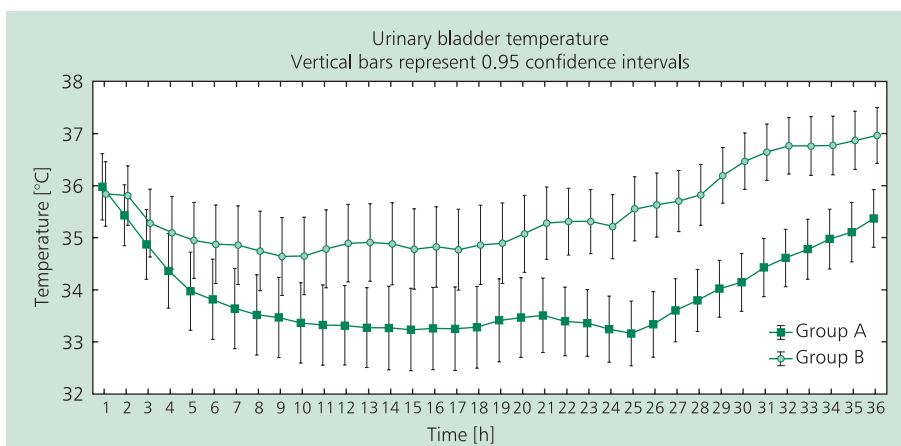


Figure 2. Urinary bladder temperature curves during the whole cooling and re-warming period. Temperature profiles are significantly different ($p < 0.001$) (group A — intravascular hypothermia, group B — traditional hypothermia)

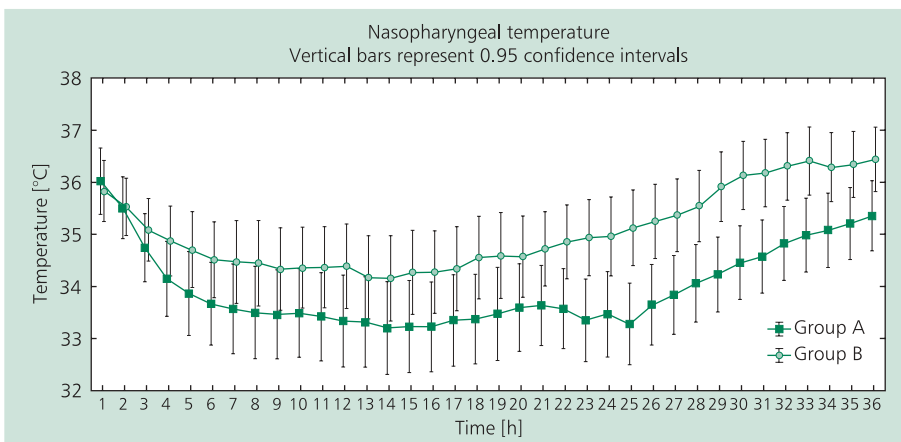


Figure 3. Nasopharyngeal temperature curves during the whole cooling and re-warming period. Temperature profiles are significantly different ($p = 0.014$) (group A — intravascular hypothermia, group B — traditional hypothermia)

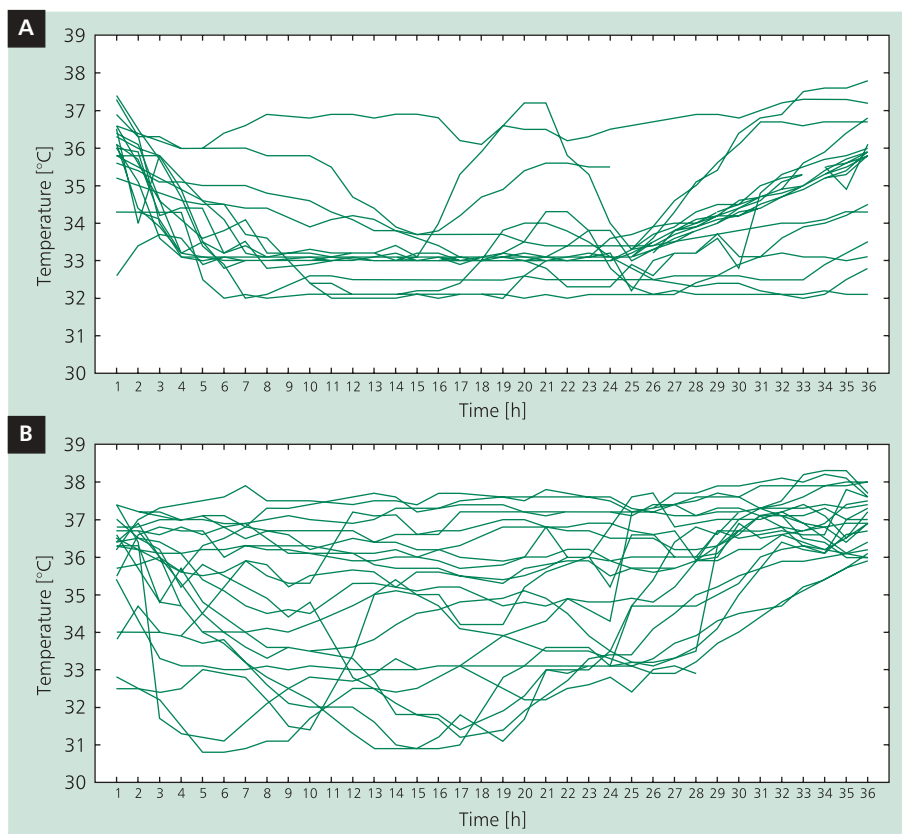


Figure 4. Plot of urinary bladder temperatures of individual patients in group A (intravascular hypothermia) (A) and group B (traditional hypothermia) (B)

Patients scheduled for cooling in our study had a mean baseline temperature of $36.1 \pm 0.9^\circ\text{C}$, already slightly lower than a normal temperature (however a body temperature $< 35^\circ\text{C}$ excluded patients from the study). This is not unusual: Lyon et al. [14] found that patients admitted to hospital after an out-of-hospital CA had a mean core body temperature of only 34.3°C .

All patients who received traditional cooling in our study were initially given 30 mL/kg of ice-cold crystalloid solutions. It has been shown that this is not harmful for patient haemodynamics [15]. In our study, however, the administration of 30 mL/kg of ice-cold intravenous fluids resulted in a mean lowering of the temperature by only $0.05 \pm 0.57^\circ\text{C}$ in the first hour of cooling. This is much less compared to other authors [16].

There are a number of cooling methods and they have been recently well described in the medical literature [17]. In our study, we compared the relatively expensive intravascular hypothermia with the 'traditional', low cost method and thus the one with the greatest potential for widespread use. Intravascular hypothermia is generally considered one of the most effective methods of cooling [18, 19].

It is worth mentioning that in some of the available systems, hypothermia is also controlled by sophisticated equipment, such as with surface cooling, e.g. the Arctic Sun system which is ba-

sed on precise, microprocessor control and uses surface cooling only. In a study comparing this system to intravascular hypothermia, the systems were found to be comparable [20].

Limitations of the study

The main limitation of our study is the lack of presentation of outcome data. However, it is obvious that the outcome following CA depends on many factors, not only the method of cooling and we aimed to concentrate on the efficiency of cooling. The choice of cooling method was also relatively narrow. We were able to control temperature more precisely with only one method of internal cooling compared to only one external technique, but there are many different cooling methods available [16].

CONCLUSIONS

On the basis of our results, we may conclude that intravascular cooling provides more precise temperature control than the traditional technique. We confirmed that this system is safe, very easy to use, and extremely effective.

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Conflict of interest: none declared

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Porównanie wewnątrznaczyniowej i tradycyjnej techniki hipotermii po zatrzymaniu krążenia

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Streszczenie

Wstęp: Hipotermia terapeutyczna jest obecnie najlepiej udokumentowaną metodą poprawy wyników neurologicznych u chorych po zatrzymaniu krążenia i skutecznej resuscytacji. Istnieje wiele metod obniżania temperatury ciała, ale brakuje danych wskazujących na to, że jakkolwiek z metod w większym stopniu niż inne poprawia wyniki leczenia lub zwiększa przeżycie chorych. W praktyce klinicznej stosuje się zarówno proste metody z zastosowaniem chłodzenia powierzchniowego i lodowatych płynów dożylnie, jak i metody bardziej zaawansowane technologicznie. Jedną nich jest hipotermia wewnątrznaczyniowa, podczas której obniżanie temperatury ciała przeprowadza się za pomocą specjalnego cewnika znajdującego się w żyły centralnej.

Cel: Celem pracy było porównanie chłodzenia z wykorzystaniem hipotermii wewnątrznaczyniowej i metody tradycyjnej.

Metody: Prospektywne badania przeprowadzono u 41 pacjentów z ostrymi zespołami wieńcowymi, którzy nie odzyskali świadomości po pozaszpitalnym lub szpitalnym nagłym zatrzymaniu krążenia. Terapeutyczną hipotermię (32–34°C) przez okres 24 godzin prowadzono przy użyciu metody wewnątrznaczyniowej (grupa A, n = 20) lub metodą tradycyjną (grupa B, n = 21). W metodzie wewnątrznaczyniowej wykorzystano cewnik wprowadzony do żyły udowej połączony z wymiennikiem ciepła (Alsius Coolgard, Zoll, Chelmsford, MA, USA). Tradycyjne chłodzenie przeprowadzono za pomocą niekontrolowanego chłodzenia powierzchniowego oraz podaży lodowatych płynów dożylnie i dożołądkowo. Przydział pacjentów do grup badanych nie był randomizowany i zależał od dostępności sprzętu oraz preferencji lekarzy. Dane demograficzne chorych i wyjściowa temperatura ciała przed rozpoczęciem chłodzenia nie różniły się istotnie w badanych grupach. Temperaturę ciała rejestrowano co godzinę w jamie nosowo-gardłowej i pęcherzu moczowym. Główną analizowaną temperaturą była temperatura w pęcherzu moczowym, ponieważ wymiennik ciepła w grupie hipotermii wewnątrznaczyniowej jest kontrolowany przez odczyt z tego miejsca. Założono, że stabilny profil temperatury oznacza utrzymanie temperatury w pęcherzu moczowym w przedziale 32–34°C przez ostatnie 12 godzin chłodzenia. Profile temperatury zostały porównane między grupami. Dla celów wszystkich obliczeń przyjęto, że wartość współczynnika $p < 0,05$ jest statystycznie istotna.

Wyniki: Temperaturę $< 34^{\circ}\text{C}$ osiągnięto u 19 (95,0%) chorych w grupie A i u 11 (52,4%) osób w grupie B ($p = 0,004$). Stabilny profil temperatury (temp. w zakresie 32–34°C przez ostatnie 12 h chłodzenia) osiągnięto u 16 (80%) pacjentów w grupie A oraz u 3 (14,3%) osób w grupie B ($p < 0,001$). Okresy niedostatecznego chłodzenia (temp. $> 34^{\circ}\text{C}$) i nadmiernego chłodzenia (temp. $< 32^{\circ}\text{C}$) obserwowano istotnie częściej w grupie B. W grupie B temperatura była wyższa od 34°C przez 65% i niższa od 32°C przez 10% ogólnego skumulowanego czasu obserwacji wszystkich chorych, natomiast w grupie A temperatura była wyższa od 34°C przez zaledwie 15% skumulowanego czasu obserwacji i nie była nigdy niższa od 32°C. Profile temperatury różniły się istotnie między grupami w odczytach zarejestrowanych z obu miejsc pomiaru.

Wnioski: Zaprezentowana technika hipotermii wewnątrznaczyniowej zapewnia bardziej precyzyjną kontrolę temperatury w porównaniu z metodą tradycyjną.

Słowa kluczowe: hipotermia, nagłe zatrzymanie krążenia, chłodzenie

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