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Sudden cardiac arrest accompanied by severe accidental hypothermia - modifications of the standard cardiopulmonary resuscitation procedure

Rafał Czyż[1], Marcin Leśkiewicz[2], Izabela Czyż[3]

[1]Department of Emergency Medicine, Wroclaw Medical University
[2]Department of Emergency Medical Services, Wroclaw Medical University
[3]Graduate of Wroclaw Medical University

Rafał Czyż: http://orcid.org/0000-0001-5504-4543
Marcin Leśkiewicz: http://orcid.org/0000-0003-0167-1618
Izabela Czyż: http://orcid.org/0000-0002-7838-1670

Address for correspondence:
Rafał Czyż, Department of Emergency Medicine Wroclaw Medical University, Wroclaw. Poland; e-mail: rafalczyz1990@o2.pl

Abstract

Severe accidental hypothermia is associated with a high mortality rate. This is related to the fact that assessment and treatment may be difficult: the severity of determining the presence of pulse and breathing, the significant sensitivity of the patient to a change in body position, difficulty in the instrumental protection of airways, ease of ventricular fibrillation occurrence and many other risks. A well-prepared medical team, coordinated actions based on current medical guidelines and recommendations, give a chance to save patients even after a few hours of cardiopulmonary resuscitation. Despite the availability of advanced devices for heating and supporting cardiovascular function in patients with cardiac arrest with coexisting hypothermia, basic activities such as isolation and protection against heat loss are critical important rescue tasks necessary for effective treatment of the patient.

In connection with the above, this article summarizes current information about sudden cardiac arrest with coexisting hypothermia. The following aspects were discussed: definition, epidemiology, diagnosis and assessment of hypothermia severity and modifications of standard resuscitation algorithm in the case of coexisting hypothermia.

Key words: accidental hypothermia, body temperature, core temperature, rewarming, cardiopulmonary resuscitation, CPR in special circumstances

Introduction and aim of work

Despite the fact that hypothermia can develop in every human being, in every place in the world and at any time of the year it often remains undiagnosed and constitutes a diagnostic riddle for medical personnel. In addition, attention should be paid to the fact that undetected quickly enough can in a short time lead to breakdown of the critical life parameters of the patient, and as a result also lead to sudden cardiac arrest and death of the patient.

The aim of this study is to draw attention to the validity of current guidelines of conduct, diagnostic recommendations and necessary to introduce modifications in the algorithm of cardiopulmonary resuscitation in a patient in sudden cardiac arrest with coexisting hypothermia.

Description of knowledge

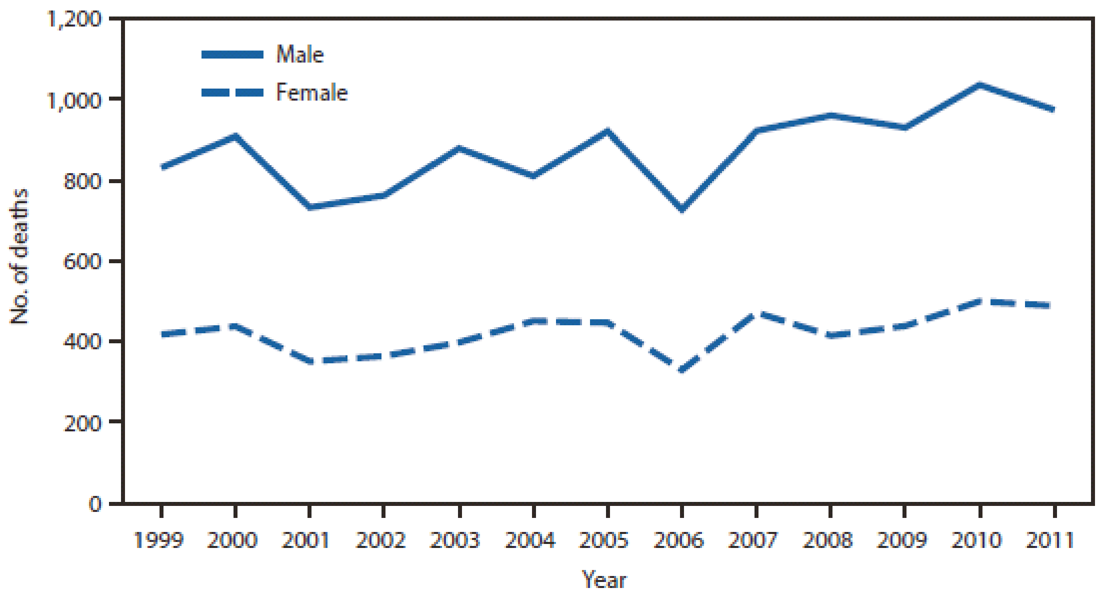
Definition

Accidental hypothermia is defined as an involuntary drop of the body core temperature <35 ◦C (95 F) [1]. In the international scientific literature one can find descriptions of several physiological experiments carried out by John Hunter and James Curry as early as 1700, which concerned accidental hypothermia. However, detailed physiological experiments in this field were not carried out until the beginning of the 20th century. It was only in the 1930s and 1940s that it provided more impetus to investigating the physiotherapy with measuring core temperatures [2].

Epidemiology

Every year in the world there is a very large number of people who have died as a result of unfavorable effects of low temperatures. The Centers for Disease Control and Prevention data show that in the years 1990-2011 there were 16 911 deaths in total which were associated with exposure to excessive natural cold (Fig. 1.). The highest yearly total of hypothermia-related deaths (1536) was in 2010 and the lowest (1058) in 2006. Approximately 67% of hypothermia-related deaths were among males [3]. In 2017 there were 34 deaths in Scotland that involved hypothermia. Since 2000, there have been 1,253 deaths involving hypothermia, of which 58% were male and 42% were female [4]. According to the official data of the Central Statistical Office for the period of 2009–2012, hypothermia was the primary cause of death in 1836 residents in Poland [5]. However, it is estimated, that the number of deaths caused by low temperatures may be several times higher. The prevalence of accidental hypothermia may have been 5.05 cases per 100.000 residents per year. [5].

Figure 1. Number of hypothermia-related deaths, by sex, in the United States during 1999-2011.



* Deaths attributed to exposure to excessive natural cold as underlying and contributing causes of death, which were coded as X31, T68, and T69 according to the International Classification of Diseases, 10th Revision.

(Source: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6151a6.htm)

Diagnosis and assessment of hypothermia severity

Hypothermia is diagnosed in any patient with a core temperature <35°C, or where measurement unavailable, a history of exposure to cold, or when the trunk feels cold [6].

Risk factors that may affect the victim's hypothermia [1]:

- thermoregulatory disorders - in the elderly and very young,
- alcohol or drug ingestion,
- exhaustion,
- illness,
- injury.

A good and practical method of clinical evaluation of the patient in terms of accidental hypothermia in pre-hospital treatment is the use of the Swiss Staging Scale [7]. In severe environmental conditions, accurate deep temperature measurement may be difficult or completely impossible to perform. The Swiss Staging Scale uses such parameters of the injured person as: level of consciousness, vital signs, and core temperature (if available). There are five stages of the Swiss Staging System where the last of them is associated with certain signs of the victim's death, however, there are reports of further cases of lowering the temperature range in this case so the given temperature of 13.7 °C is only conventional (Tab.1). A staging system is a valuable clinical tool to facilitate triage and emergency treatment. However, definitive assessment of the severity of hypothermia requires accurate core temperature measurement [9].

Tabel 1. The Swiss Staging System.

Stage	Severity of hypothermia	Clinical Symptoms	Core temperature (°C)	Core temperature (°F)
HT I	Mild hypothermia	Conscious, shivering	35 - 32 °C	95.0-89.6 °F
HT II	Moderate hypothermia	Impaired consciousness without shivering	32 - 28 °C	89.6-82.4 °F
HT III	Severe hypothermia	Unconscious, vitals signs present	28 - 24 °C	82.4 - 75.2 °F
HT IV	Cardiac arrest or low flow state	No or minimal vital signs	< 24 °C	< 75.2 °F
HT V	Death due to irreversible hypothermia	---	< 13.7 °C [8]	< 56.66 °F

(Source: own elaboration based on: Durrer B, Brugger H, Syme D.: The medical on-site treatment of hypothermia: ICAR-MEDCOM recommendation. High Alt Med Biol. 2003; 4 (1): 99-103)

The core temperature in a patient who is suspected of coexisting accidental hypothermia should be investigated as soon as possible. A good anatomical place for measuring the core temperature of the patient in hypothermia is the lower one third of the esophagus depht. What is important, the temperature in this place correlates well with the temperature of the heart. An alternative and recommended place for measuring the core temperature is the tympanic membrane using thermistor technique. It is important that the sensor of the thermometer, having a sufficiently low scale of measurement, should be placed in the correct place and adequately protected against possible unintentional displacement, especially during cardiopulmonary resuscitation. The results of temperature measurements in the rectum and bladder are usually lower than the actual core temperature, which is why they are not recommended places of core temperature measurement in patients with severe hypothermia.

Resuscitation of a patient with coexisting accidental hypothermia

A decrease in the core temperature of injured person by 1°C is associated with a decrease in the tissue demand for oxygen by about 6%. It is estimated that the brain of a person in severe hypothermia, at around 18°C, is able to survive cardiac arrest approximately 10 times longer than in normothermia (37°C) [10]. This is also consistent with the case reports of long-term resuscitation in patients with coexisting hypothermia, where it ended successfully with the lack of coexisting neurological deficits. There are scientific reports describing clinical cases of saving a patient from a core temperature of 13.7°C [8] and resuscitation lasting about 6 hours and 30 minutes [11]. Guidelines and recommendations draw attention to pay special attention to precise and accurate determination of signs of life in the patient, which in this clinical situation may be particularly difficult. A slow, poorly perceptible irregular pulse wave may occur with coexisting weak rare breath. The European Resuscitation Council recommends extending the standard time to assess patient parameters from 10 seconds to 1 minute. If it is possible and available on accident spot, it also recommends using ECG monitoring to detect electrical activity of the heart [1]. Therefore, the decision to withhold from resuscitation activities may be difficult to take. The only situations in which resignation is permitted are [12]:

- lethal injury,

- fatal illness,
- prolonged asphyxia,
- if the chest is incompressible.

In all other hypothermic patients, the traditional guiding principle that 'no one is dead until warm and dead' should be considered.

Modifications to cardiopulmonary resuscitation according to European Resuscitation Council Guidelines 2015

Searching for signs of life in an injured person with the probability of accidental hypothermia should be extended even to about 1 minute. It is recommended to look for a pulse on the central artery and if a cardio monitor is available to perform heart rhythm analysis [1]. It may also be helpful to use echocardiography to analyze cardiac output and possible peripheral perfusion. Hypothermia may cause stiffness of the patient's chest wall.

This can cause heaviness in patient ventilation and in compressing the victim's chest. Therefore, it is worth engaging the largest possible number of medical personnel capable of performing high quality chest compressions in resuscitation efforts, so as to guarantee regular changes between these persons every 2 minutes. If available, you can also consider using a mechanical device to compress the patient's chest in sudden cardiac arrest. One should remember about early confirmation of hypothermia in a patient in cardiac arrest with maintaining a permanent place of subsequent measurements. It is not recommended to delay early tracheal intubation if there are indications for it [1]. The benefits of proper oxygenation and aspiration of gastric contents outweigh the risks associated with developing ventricular fibrillation. Patients with hypothermia may have reduced susceptibility to medications and attempts to electrically stimulate the heart. In addition, along with the reduced metabolism of drugs in hypothermia, these drugs may accumulate toxic in plasma. In connection with the above, the 2015 European Resuscitation Council guidelines recommend the following strategy for administering medicines [1] (Tab. 2.).

Tabel 2. The recommended schedule of drug administration to patient in cardiac arrest with coexisting accidental hypothermia.

Core temperature	**The method of drug supply to patient in sudden cardiac arrest**
≤ 30ºC	Suspension of drug supply
30ºC – 35ºC	Twice the time intervals between successive doses of drugs
≥ 35ºC	Standard intervals between successive doses of drugs

(Source: own elaboration based on: Truhlář A, Deakin C.D, Soar J. et. al.: European Resuscitation Council Guidelines for Resuscitation 2015: Section 4. Cardiac arrest in special circumstances. Resuscitation. 2015; 95: 148-201)

As mentioned earlier, the effectiveness of electrotherapy in a patient with accidental hypothermia can be significantly reduced. Bradycardia is a physiological phenomenon that accompanies severe hypothermia. Therefore, electrostimulation of the patient is not recommended except when bradycardia persists after heating the patient. The current guidelines of the European Resuscitation Council indicate that in the event of a pulseless VT / VF rhythm, immediate defibrillation is recommended [1]. Recommendations emphasize that in the absence of effect on a defibrillation threefold, further discharges should be delayed until the core temperature increases ≥30ºC [1].

A very important element not only in the course of cardiac arrest, but in every hypothermic patient is proper thermal insulation and effective methods of heating the patient. It should always be borne in mind that with the patient in moderate and severe hypothermia one should proceed with caution due to the possibility of inducing severe arrhythmias. Early cutting of clothes is a better method than prolonged removal of clothes, which may additionally increase the patient's mobility. It is also necessary to dry the patient's body and then isolate them, for example, with a metallized foil or specialist heating blankets. In the conditions of the emergency medical team, early evacuation of the patient to the interior of the ambulance should be considered in order to continue heating. For this purpose, heating can be switched on in the medical ambulance compartment, chemical heating packs can be placed around the groin and armpits of the patient. You can also start warm intravenous infusions and administer warm, hydrated medical oxygen. Infusion fluids should be heated to about 40°C, however, it should be remembered that the loss of heat during the fluid flow through the transfusion set at a length of about 150cm results in a significant loss of heat. One of the studies shows that the saline solution preheated to 60°C and rolled at the rate of 1000 ml per hour will reach the temperature of 39°C at the end of the 180-cm drain [13]. However, it should be remembered that the effectiveness of such methods is limited (Tab. 3.), therefore their use cannot delay the transport to a specialized department where advanced techniques of patient heating are available.

The target place of patient transport in hypothermia should be selected based on the therapeutic options of the center. Every patient at the stage of hypothermia from II^{o} to IV^{o} with signs of hemodynamic instability (systolic pressure <90 mmHg, ventricular arrhythmia, central temperature <28°C) should be transported to a hospital where extracorporeal life support systems (ECLS) are available [1]. The correct procedure will also be to promptly notify the target unit about the patient's transportation in such a state in order to create a therapeutic team, prepare appropriate equipment and plan further therapeutic treatment. If the patient does not have ventricular fibrillation, active external heating methods (e.g.: warm air heating systems) and minimally invasive methods (e.g.: warm intravenous infusions) should be used. With a core temperature <32 ◦C and potassium <8 mmol L^{-1}, consider ECLS rewarming [8]. Most ECLS rewarming have been performed using cardiopulmonary bypass, but more recently veno-arterial extracorporealmembrane oxygenation (VA-ECMO) has become the preferred method. It is due to rapid availability, the need for less anticoagulation, and the potential to prolong cardiorespiratory support after rewarming [1].

Tabel 3. Effectiveness of selected rewarming techniques.

Technique	**Rewarming rate (approximate value)**
Without cardiac support	
Warm environment and clothing, warm sweet drinks, and active movement	2°C/hr (dependent on metabolic rate)
Active external and minimally invasive rewarming (warm environment; chemical, electrical, or forced-air heating packs or blankets; and warm parenteral fluids)	0.1–3.4°C/hr
Peritoneal dialysis	1–3°C/hr
Hemodialysis	2–4°C/hr
Thoracic lavage	3°C/hr
Venovenous ECMO	4°C/hr
With cardiac support	
Venoarterial ECMO (extracorporeal membrane oxygenation)	6°C/hr
Cardiopulmonary bypass (CPB)	9°C/hr

(Source: own elaboration based on: Brown D.J, Brugger H, Boyd J, Paal P.: Accidental hypothermia. N Engl J Med. 2012; 367: 1930-1938)

Summary

The most important factor affecting the effectiveness of medical treatment in a patient with cardiac arrest and coexisting hypothermia is the speed of identification of such a factor. Early analysis of the reversible causes of cardiac arrest can effectively guide the rescue team to the appropriate diagnosis and targeted therapy. It may also be helpful to analyze, for example, the circumstances of the incident, information from the interview and some elements of the physical examination of the patient. By modifying the standard resuscitation algorithm due to this additional factor, it is possible to significantly increase the patient's chances of survival. What's more, the protective effect of low temperature on the brain tissue by reducing the patient's metabolism means that even a few hours of cardiopulmonary resuscitation can be effective and the patient can leave the whole event without any neurological deficits. Systematic training of emergency medical teams members and emergency departments crew may further influence the survival rate of patients after the cardiac arrest incident with coexisting accidental hypothermia.

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