From HEMS to SAR, from sea to mountains, from urban to combat, a thorough Congress.

This is Remote.
Drowning and hypothermia: principles of treatment

Giacomo Strapazzon MD PhD

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Disclosure of any financial relationships

I do not have any financial relationship or conflict of interest to disclose
Objectives

This lesson will focus on:

- Definition and pathophysiological aspects
- Clinical diagnosis and prehospital treatment
Definition

Drowning is a process resulting in primary respiratory impairment from submersion or immersion in a liquid medium.
Definition

Drowning is a process resulting in primary respiratory impairment from submersion or immersion in a liquid medium.

Implicit in this definition is that a liquid/air interface is present at the entrance of the victim’s airway, preventing the victim from breathing air.
Submersion vs. Immersion

Submersion occurs when the face is underwater or covered in water. Asphyxia and cardiac arrest occurs within a matter of minutes of submersion.

Immersion [...] is when the head remains above water, in most cases by means of the support of a lifejacket. [...] the victim remains immersed with an open airway and becomes hypothermic [...].
Definition

Accidental hypothermia is defined as an involuntary drop of the body core temperature <35° C.
Case report

Outcome of accidental hypothermia with or without circulatory arrest
Experience from the Danish Prætø Fjord boating accident


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*****Department of Anaesthesia and Intensive Care, Aarhus University Hospital Skjellerup, Denmark
Case report

- 13 adolescents 2 adults leaves Praesto harbor in a dragon boat
- The boat capsizes during attempt to turn, and all occupants are immersed in 2°C saltwater
- A 16 year old girl manages to swim ashore and alerts emergency services
- First unconscious victim rescued by emergency services
Case report

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<th>Patient</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Body mass index (kg/m²)</th>
<th>Time to first EMS contact (min)</th>
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<td>Male</td>
<td>21.8</td>
<td>121</td>
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<td>18.4</td>
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<tr>
<td>#4</td>
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<td>153</td>
<td>3</td>
<td>15.5</td>
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<td>19.4</td>
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<td>Median (range)</td>
<td>16 (15-17)</td>
<td></td>
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<td>27.5</td>
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+ one drowned patient
European Resuscitation Council Guidelines for Resuscitation 2015
Section 4. Cardiac arrest in special circumstances

Anatoliy Truhlář a,b,c,d, Charles D. Deakin e, Jasmeet Soar a, Gamal Eldin Abbas Khalifa a, Annette Alfonzo a, Joost J.L.M. Bierens e, Gutterm Brattebo a, Hermann Brugger a, Joel Dunning a, Silvija Hunyadi-Antićević a, Rudolph W. Koster d, David J. Lockey e,f, Carsten Lott a, Peter Paal a,g, Gavin D. Perkins e, Claudio Sandroni e, Karl-Christian Thies e, David A. Zideman a, Jerry P. Nolan e,f, on behalf of the Cardiac arrest in special circumstances section Collaborators 1

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5 Emergency and Disaster Medicine, Six October University Hospital, Cairo, Egypt
6 Departments of Anesthetic and Intensive Medicine, Victoria Hospital, Ethical, Fige, UK
7 Society to Rescue People from Drowning, Amsterdam, The Netherlands
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10 Department of Cardiothoracic Surgery, James Cook University Hospital, Middlesbrough, UK
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23 School of Clinical Sciences, University of Bristol, UK

http://www.cprguidelines.eu/
Prehospital management of drowning patients
Principles of treatment

The duration of submersion is a key determinant of outcome from drowning. Submersion exceeding 10 min is associated with poor outcome.
Drowning chain of survival
Principles of treatment

Bystanders play a critical role in early rescue and resuscitation. Resuscitation strategies for those in respiratory or cardiac arrest continue to prioritise oxygenation and ventilation.

Expert opinion suggests that cricoid pressure applied by trained and skilled personnel in casualties without a secured airway may reduce gastric inflation and enhance ventilation in drowning.
Unresponsive and not breathing normally?

Shout for help and call emergency services

Open airway

Give 5 rescue breaths / ventilations supplemented with oxygen if possible

Signs of life?

Start CPR 30:2

Attach AED and follow instructions
Fluid in the airway

In some situations, massive amounts of foam caused by admixing moving air with water are seen coming out of the mouth of the victim. Do not try and attempt to remove the foam as it will keep coming. Continue rescue breaths/ventilation until an ALS provider arrives and is able to intubate the victim.
Resuscitation - ALS

Take care to ensure optimal preoxygenation before attempting tracheal intubation. Pulmonary oedema fluid may pour from the airway and may need continuous suctioning […].

Set positive end expiratory pressure to at least 5–10 cm H₂O. Decompress the stomach with a gastric tube.
Resuscitation - ALS

As soon as possible, use information from monitoring modalities such as the ECG trace, ETCO$_2$ and echocardiography to confirm the diagnosis of cardiac arrest.

If the victim is in cardiac arrest, follow standard ALS protocols. If the victim is hypothermic, modify the approach in accordance with the guidance for treatment of hypothermia.
Discontinuing resuscitation efforts

A victim of drowning is notoriously difficult. No single factor can accurately predict good or poor survival with certainty. Frequently, decisions made in the field later prove to have been incorrect.
Discontinuing resuscitation efforts

A victim of drowning is notoriously difficult. No single factor can accurately predict good or poor survival with certainty. Frequently, decisions made in the field later prove to have been incorrect.

Continue resuscitation unless there is clear evidence that such attempts are futile (e.g. massive traumatic injuries, rigour mortis, putrefaction, etc.), or timely evacuation to a medical facility is not possible.
Accidental hypothermia

Hypothermia should be suspected in cold or moderate climates throughout the year in urban as well as rural areas.
Main physiological effects of hypothermia

<table>
<thead>
<tr>
<th>System</th>
<th>Parameter</th>
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<tbody>
<tr>
<td>CENTRAL NERVOUS</td>
<td>• Reflexes become increasingly sluggish as body temperature falls and become absent $\approx 28$-$30^\circ$C.</td>
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<td>• EEG shows burst suppression $\approx 22^\circ$C and becomes isoelectric $\approx 18$-$20^\circ$C.</td>
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<td>RESPIRATORY</td>
<td>• Tidal volume, respiratory rate, pulmonary/thoracic compliance decrease.</td>
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<td>• Oxygen consumption and CO$_2$ production fall by about 50% at $30^\circ$C.</td>
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<td>• Sensitivity to CO$_2$ is attenuated, although the hypoxic drive is maintained to deeper levels of hypothermia.</td>
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Hypothermia and oxygen consumption

Oxygen consumption ~6% decreased per 1°C (1.8°F)
Hypothermia and oxygen consumption

28°C core temperature oxygen consumption → 50%
Hypothermia and hypoxia tolerance

Increase of tolerance to low or no-flow

- Hypoxia uptake (%)
- Brain hypoxia tolerance (min)

Core temperature °C

McCullough et al., Ann Thorac Surg 1999
Paal, Strapazzon et al. SJTRE 2016
On-site staging of hypothermia

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Durrer and Brugger. High Alt Med Biol 2003
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- *Core temperature*:<br>  
  - I: Responsive, shivering: 35 - 32 °C
  - II: Somnolent, not shivering: 32 - 28 °C
  - III: Unresponsive: 28 - 24 °C
  - IV: No or minimal vital signs: <24 °C

- **RISK OF CARDIAC INSTABILITY!**
  - Ventricular arrhythmias
  - SBP <90mmHg

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Durrer and Brugger. High Alt Med Biol 2003
Thrular, Brugger et al. Resuscitation 2015
## On-site staging of hypothermia

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<24°C NO VITAL SIGNS
- Apnea
- PEA
- Ventricular fibrillation
- Asystole
- Isoelectric EEG
- Apparent death

Durrer and Brugger. High Alt Med Biol 2003
Thrular, Brugger et al. Resuscitation 2015
Is clinical staging of accidental hypothermia reliable?

- Yes and it is not influenced by individual/clinical factors
- Yes even if it there is a clinical variability
- Yes and core temperature measurement is not necessary
Is clinical staging of accidental hypothermia reliable?

- Yes and it is not influenced by individual/clinical factors
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- Yes and core temperature measurement is not necessary
T_{core} measurement
Core temperature measurement in the field

- Esophagus
- Bladder
- Rectum
- Epitympanic
- Skin: (zero) heat flux methods
On-site core temperature reading in patients with spontaneous circulation

Core temperature measurement in the field

Strapazzon et al. SJTRE 2014

Fig. 1 Epitympanic temperature ($T_{\text{etm}}$) at room temperature (a; $23.2 \pm 0.4$ °C) and low temperature (b; $-18.7 \pm 1.0$ °C) in relation to exposure time in minutes. Data are displayed for group A (solid lines; exposure to low followed by room temperature), group B (dotted lines; exposure to room followed by low temperature), with insulation of the ear (black) and without insulation of the ear (grey).
Core temperature measurement in severe trauma patients

Core temperature

Prehospital

- $T_c > 35^\circ C$: 2 (3%)
- $T_c < 35^\circ C$: 7 (6%)
- $T_c$ unknown: 95 (91%)

In-hospital

- $T_c > 35^\circ C$: 20 (19%)
- $T_c < 35^\circ C$: 35 (34%)
- $T_c$ unknown: 49 (47%)

P-value <.05

Strapazzon et al. HAMB 2014
Prehospital management of hypothermic patients without cardiac arrest
## General principles

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- Warm sweet drinks
- Active movement
- Warm environment

Brown D, Brugger H et al. NEJM 2012

Durrer and Brugger. High Alt Med Biol 2003
Thrular, Brugger et al. Resuscitation 2015
**General principles**

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- Careful handling

Henriksson et al. Prehosp Disast Med 2012

Durrer and Brugger. High Alt Med Biol 2003
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- Careful handling
- Full body insulation

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Henriksson et al. Prehosp Disast Med 2012

Durrer and Brugger. High Alt Med Biol 2003
Thrular, Brugger et al. Resuscitation 2015
Insulation

Remove wet clothes while minimising excessive movement of the victim.
Insulation

Remove wet clothes while minimising excessive movement of the victim.

Removal of wet clothing or use of a vapour barrier seems to be equally effective to limit heat loss.
# Insulation

Table 2. The effect on thermoregulation and cold discomfort\(^a\)

<table>
<thead>
<tr>
<th>Insulation protocol</th>
<th>Metabolic rate (W/m(^2))</th>
<th>ΔCore body temperature (°C)</th>
<th>ΔMean skin temperature (°C)</th>
<th>Heart rate (beats/min)</th>
<th>Cold discomfort (0–10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One woolen blanket</td>
<td>98 ± 12</td>
<td>−0.4 ± 0.2</td>
<td>1.5 ± 0.4</td>
<td>69 ± 6</td>
<td>5 (3.25–6)</td>
</tr>
<tr>
<td>Wet clothing removal + one woolen blanket</td>
<td>85 ± 11(^b)</td>
<td>−0.3 ± 0.2</td>
<td>2.5 ± 0.7(^b)</td>
<td>70 ± 7</td>
<td>3 (2–5)</td>
</tr>
<tr>
<td>Vapor barrier + one woolen blanket</td>
<td>84 ± 17(^b)</td>
<td>−0.3 ± 0.2</td>
<td>2.7 ± 0.8(^b)</td>
<td>67 ± 8</td>
<td>4 (2–4.75)(^c)</td>
</tr>
<tr>
<td>Two woolen blankets</td>
<td>81 ± 10(^b)</td>
<td>−0.3 ± 0.2</td>
<td>2.3 ± 0.7(^b)</td>
<td>64 ± 5</td>
<td>3.5 (1.5–4)(^c)</td>
</tr>
</tbody>
</table>

\(^a\) Volunteer subjects (n = 8) wearing wet clothing in a climatic chamber at −18.5°C with still wind conditions. Values are mean ± SD or median (interquartile range) during 4 insulation protocols.

\(^b\) Significantly different from 1 woolen blanket (repeated-measures analysis of variance), P < .05.

\(^c\) Significantly different from one woolen blanket (Friedman’s test), P < .05.
Prehospital heat loss prevention

Minimally Invasive Rewarming: (hypothermia burrito)

1. Outer wind & waterproof +/- reflective tarp (prehospital only)
2. Insulation or heating pad*
3. Replace wet clothes if practical, otherwise wrap patient in plastic
4. Forced air, chemical or electrical heating device(s)*
5. Insulating blanket
6. Insulate the head**
ALS, triage and transport

Related to the hypothermia degree and haemodinamic status.

Truhlar, Brugger et al. Resuscitation 2015
Paal, Strapazzon et al. SJTRE 2016
Prehospital management of hypothermic patients with cardiac arrest
Is there any difference in BLS resuscitation of an hypothermic patient?
Resuscitation

Standard high quality CPR (30:2).
Do not delay careful tracheal intubation when it is indicated.

The advantages of adequate oxygenation and protection from aspiration outweigh the minimal risk of triggering VF by performing tracheal intubation.
Resuscitation – ALS

Check for signs of life for up to 1 min. Palpate a central artery and assess the cardiac rhythm (if ECG monitor available).

Echocardiography, near-infrared spectroscopy or ultrasound with Doppler may be used to establish whether there is (an adequate) cardiac output or peripheral blood flow.

If there is any doubt, start CPR immediately.
Resuscitation - ALS

Hypothermia can cause stiffness of the chest wall, making ventilations and chest compressions difficult.

Consider the use of mechanical chest compression devices.

Once CPR is under way, confirm hypothermia with a low-reading thermometer.
Mechanical chest compression!

Autopulse  Easypulse  LUCAS3
The hypothermic heart may be unresponsive to cardioactive drugs. Drug metabolism is slowed.

Given that adrenaline may induce myocardial injury, it is reasonable to withhold adrenaline, other CPR drugs until the patient has been warmed to a core temperature ≥30°C. Once 30°C has been reached, the intervals between drug doses should be doubled when compared to normothermia (i.e. adrenaline every 6–10 min).
Resuscitation - ALS

If VF persists after three shocks, delay further attempts until core temperature is ≥30°C.
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Arrhythmias other than VF tend to revert spontaneously as core temperature increases, and usually do not require immediate treatment.
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Bradycardia is physiological in severe hypothermia. Cardiac pacing is not indicated unless bradycardia associated with haemodynamic compromise persists after rewarming.
Resuscitation - ALS

CPR during transport (e.g. Autopulse, Easypulse, LUCAS3, intermittent CPR).
Resuscitation - ALS

ECMO/CPB centre – triage.
On-site staging and management

Patient's skin feels cool on examination or core temperature <35°C

- Vital signs present

Primary cardiac instability
- Systolic blood pressure
- Asystole
- Arrhythmias
- Core temperature <35°C

- No
- Yes to any

- Transport to nearest hospital if required
- Consider venous or hospital treatment if unplanned

Posthospital cardiac instability
- Systolic blood pressure
- Asystole
- Arrhythmias
- Core temperature <35°C

- No
- Yes to any

- Transport to nearest hospital
- Consider venous or hospital treatment

HT 8 hr or 18 hr

- Cardiac arrest
- Cardiac arrest
- Cardiac arrest
- Cardiac arrest

- No
- Yes

HT 8 hr or 18 hr

- No
- Yes

- Transport to nearest hospital
- Consider venous or hospital treatment

- Consider cardiac arrest immediately

- No
- Yes

- Consider patient for ECG (CPR)?
- Core temperature <32°C
- Serum potassium ≥4.5 mEq/L

- No
- Yes

- Transport to hospital with ECMO/CPR
- Do not terminate CPR

- No
- Yes

- Reassess with ECMO/CPR
- CPR with ECMO/CPR
- CPR with ECMO/CPR

- No
- Yes

- Consider termination of CPR

Brown, Brugger et al. NEJM 2012
Paal, Strapazzon et al. SJTRE 2016
## On-site staging of hypothermia

<table>
<thead>
<tr>
<th>Stage</th>
<th>Clinical signs</th>
<th>Core temperature</th>
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<tbody>
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<td>I</td>
<td>Responsive, shivering</td>
<td>35-32°C</td>
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<td>II</td>
<td>Somnolent, not shivering</td>
<td>32-28°C</td>
</tr>
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<td>III</td>
<td>Unresponsive</td>
<td>28-24°C</td>
</tr>
<tr>
<td>IV</td>
<td>No or minimal vital signs</td>
<td>&lt;24°C</td>
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- Obvious signs of fatal injury
- Entire body frozen solid
- Serum potassium >12mmol/L
- Conditions unsafe for the rescuer

CONSIDER TERMINATION OF CPR

Durrer and Brugger. High Alt Med Biol 2003
Thrular, Brugger et al. Resuscitation 2015
### On-site staging of hypothermia

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- Obvious signs of fatal injury
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- Serum potassium >12mmol/L
- Conditions unsafe for the rescuer

**CONSIDER TERMINATION OF CPR**

There are no clinical or instrumental reliable signs of death in a hypothermic patient!

---

Durrer and Brugger. High Alt Med Biol 2003
Thrular, Brugger et al. Resuscitation 2015
Next steps

• **Education & protocols**
  - frontline responders
  - dispatch centres
  - hospitals

• **Regional Hypothermia Coordinators**

• **Hypothermia Survival Chain**
Case report

Hypothermic Cardiac Arrest With Full Neurologic Recovery After Approximately Nine Hours of Cardiopulmonary Resuscitation: Management and Possible Complications

Alessandro Forti, MD; Pamela Brugnara, MD; Simon Rauch, MD; Marziana Crucitti, MD; Hermann Brugger, MD; Giovanni Cipriotti, MD; Giuseppe Simpazza, MD, PhD

*Corresponding Author. Email: giuseppe.simpazza@wccn.edu

We describe full neurologic recovery from accidental hypothermia with cardiac arrest despite the longest reported duration of mechanical cardiopulmonary resuscitation (CPR) and extracorporeal life support (6 hours, 42 minutes). Clinical data and blood samples were obtained from emergency medical services (EMS) and the intensive care department. A 32-year-old man experienced a witnessed hypothermic cardiac arrest with a core temperature of 26°C (78.8°F) during a summer thunderstorm; he received mechanical CPR for 3 hours and 42 minutes, followed by 5 hours of extracorporeal life support. The use of a standard operating procedure that integrates a technical mountain rescue performed by EMS, optimizes prolonged CPR to the hub hospital, and enables prompt placement of extracorporeal life support is described and discussed. Three months postdischarge, the patient had recovered completely (Glasgow Outcome Score of 5) and resumed normal daily life. Neurologically intact survival from hypothermic cardiac arrest is common, suggesting that aggressive resuscitation measures are warranted. There is a need for the establishment of a clear standard operating procedure and multidisciplinary education and training to further optimize the patient survival chain from on-site image and treatments to inpatient extracorporeal life support and postresuscitation care. (Ann Emerg Med. 2018;0:0.)

Case report
Case report
Thanks for your attention

giacomo.strapazzon@eurac.edu