The Danish Præstø Fjord Boating Accident 11-02-2011
Accidental Hypothermia and circulatory arrest in 7 young victims

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Dragon Boat
Præstø Fjord, February 11, 2011

- 13 students and 2 teachers,
- Capsized approx. 11:22
- In 2° C cold salt water
- Depth 2-5 m
- Air temperature 4° C
- Wind speed 7 m/s and increasing
- A student reaches shore
  - swimming 500 m.
- Walks 2.1 km to nearest town
- Calls EMS at 12:43
Purpose: An attempt to beat a previously set school record

Dragon boat experience: Only the sports teacher
Swimming skills: 6 good
7 basic or bad
2 no skills

Sequence of Events
1. Wearing swim-vests - the 15 people set out from Præstø harbor at 11:00 AM
2. An eyewitness noticed that they did not appear to be rowing in synchrony.
3. Two people swapped seats, causing a 15 kg bias on the port side of the craft.
4. The boats freeboard was 0.25 m
5. A 24 degree list would be enough to cause water to enter the boat.
6. A student had a GPS watch strapped to his swim-vest
7. Deteriorating weather conditions and rough seas caused the teacher to abandon
8. As the turn was made they created a wave which capsized the boat
9. The all went overboard and the boat ended upside down – at 11:22 AM
Between 13:10 and 14:19 - 7 severely hypothermic victims with cardiac arrest were recovered from the water.

- 6 victims are taken by helicopter to Rigshospitalet (RH) in Copenhagen
- 1 victim was taken by ambulance to a local hospital

- 7 other victims were hypothermic but with spontaneous circulation and brought to local hospitals.
- One - The Sports Teacher - was missing.
<table>
<thead>
<tr>
<th>Patient</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arrival</strong> EMS (min)</td>
<td>13:20</td>
<td>13:20</td>
<td>14:14</td>
<td>14:14</td>
<td>14:14</td>
<td>14:19</td>
<td>13:10</td>
</tr>
<tr>
<td>GCS</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Intubation/ventilation (y/n)</td>
<td>n</td>
<td>n</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>CPR (y/n)</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Helicopter</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Rescue boat and Helicopter</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Rescue boat and ambulance</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
</tbody>
</table>
Between 13:45 -15.00 the 6 victims arrived at Rigshospitalet’s Trauma and Heart Center by helicopters.

Another helicopter brought a mobile Extracorporeal Circulation system to a local hospital and later transfers the patient at to a tertiary center with cardiothoracic facilities.
Fig 2 | A: an alternative venous-venous extracorporeal life support (ECLS) cannulation; deoxygenated blood is drained from the femoral vein with oxygenated blood being returned to the right atrium. B-D: various venous-arterial configurations. B: blood is drained from the femoral vein and returned to the femoral artery where oxygenated blood flows in a retrograde direction up along the aorta; when some residual cardiac function remains, oxygenated ECLS blood mixes with deoxygenated blood ejected from the left ventricle. C: a cannulated carotid artery, a site often used in infants. D: transthoracic right atrial and aortic cardiopulmonary bypass cannulas. Blue: intravascular and intracardiac deoxygenated blood; red: intravascular oxygenated blood; dark red: intravascular and intracardiac mixed oxygenated and deoxygenated blood.
**Time interval from Accident to ECMO Stop**

7 patients surviving hypothermic drowning and circulatory arrest

Lowest recorded temperature - median (range) : 18.4 (15.5-20.2) Celcius

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Time from accident to first EMS* contact</td>
<td>121 (108-169) min</td>
</tr>
<tr>
<td>3.</td>
<td>Duration of chest compression</td>
<td>65 (56-125) min</td>
</tr>
<tr>
<td>4.</td>
<td>Time from accident to ECMO</td>
<td>226 (178-241) min</td>
</tr>
<tr>
<td>5.</td>
<td>ECMO start – ECMO stop</td>
<td>149 (109-2614) min</td>
</tr>
<tr>
<td>6.</td>
<td>Accident – ECMO stop</td>
<td>375 (287-2855) min</td>
</tr>
</tbody>
</table>

Emergency Department – ECMO start 30 (14-72) min

EMS* = Emergency Medical Service
7 patients surviving hypothermic drowning and circulatory arrest

pH levels on arrival during ECC

- ECC start
- Post-ECC (patients 1, 2, 3, 5, 6)
- ECC continues 1.9 days (patient 7)
- Post-ECC (patient 4)

Mean levels

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7 patients surviving hypothermic drowning and circulatory arrest

**Lactate levels on arrival and during ECC**

- **ECC start**
- **Post-ECC (patients 1, 2, 3, 5, 6)**
- **Post-ECC (patient 4)**
- **ECC continues 1.9 days (patient 7)**

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7 patients surviving hypothermic drowning and circulatory arrest

Potassium levels on arrival and during ECC

ECC start

Post-ECC (patients 1, 2, 3, 5, 6)

Post-ECC (patient 4)

ECC continues 1.9 days (patient 7)

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7 patients with circulatory arrest

**Sinus Rythm**

<table>
<thead>
<tr>
<th>First recorded rhythm before ECC</th>
<th>4 VF</th>
<th>2 Asystoli</th>
<th>1 PEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest temperature before ECC (Celcius)</td>
<td>18.4</td>
<td>r: 15.5-20.2</td>
<td></td>
</tr>
<tr>
<td>SR at temperature (Celcius)</td>
<td>25.1</td>
<td>r: 21.5-29.7</td>
<td></td>
</tr>
<tr>
<td>Shock to SR</td>
<td>4 Patients</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Time Is Brain--Quantified**
Jeffrey L. Saver

*Stroke* 2006;37;263-266; originally published online Dec 8, 2005;

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**Estimated Pace of Neural Circuitry Loss in Typical Large Vessel, Supratentorial Acute Ischemic Stroke**

<table>
<thead>
<tr>
<th></th>
<th>Neurons Lost</th>
<th>Synapses Lost</th>
<th>Myelinated Fibers Lost</th>
<th>Accelerated Aging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Stroke</td>
<td>1.2 billion</td>
<td>8.3 trillion</td>
<td>7140 km/4470 miles</td>
<td>36 y</td>
</tr>
<tr>
<td>Per Hour</td>
<td>120 million</td>
<td>830 billion</td>
<td>714 km/447 miles</td>
<td>3.6 y</td>
</tr>
<tr>
<td><strong>Per Minute</strong></td>
<td><strong>1.9 million</strong></td>
<td><strong>14 billion</strong></td>
<td><strong>12 km/7.5 miles</strong></td>
<td><strong>3.1 wk</strong></td>
</tr>
<tr>
<td>Per Second</td>
<td>32 000</td>
<td>230 million</td>
<td>200 meters/218 yards</td>
<td>8.7 h</td>
</tr>
</tbody>
</table>
Resuscitation from accidental hypothermia of 13·7°C with circulatory arrest

Mads Gilbert, Rolf Busund, Arne Skagseth, Paul Åge Nilsen, Jan P Solbø

(ECMO). She was transferred to the intensive-care unit after 9 h of resuscitation, rewarming, and stabilisation, and remained there for 28 days. ECMO was needed for 5 days, during which time several organ dysfunctions developed that required, in addition to ECMO, haemodiafiltration and respiratory support. Transitory haemorrhagic diathesis, atrophic gastritis, ischaemic colitis, and polyneuropathy also occurred. After intravenous sedation was stopped, the patient was mentally alert with adequate responses and spontaneously moved three of four extremities. After an unsuccessful extubation on day 11, she was tracheotomised and remained on a ventilator for 35 days, partly because of critical illness polyneuropathy. She was transferred to her local hospital by air ambulance on day 28 and moved to a rehabilitation unit on day 60.
• Mechanical ventilation
• Vasoactive Support
• Sedation
• Mild Induced Hypothermia
Brain Cell Damage

**NSE**

<table>
<thead>
<tr>
<th>Day</th>
<th>Pt 1</th>
<th>Pt 2</th>
<th>Pt 3</th>
<th>Pt 4</th>
<th>Pt 5</th>
<th>Pt 6</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Normal: < 15 mcg/L
Elevated: >30 mcg/L

Reference values for serum S-100 are 0.02–0.15 μg/l.
Tissue Perfusion and Renal Function

Lactate

Creatinin
Muscle Cells

Myoglobin

Ref: 19-49 μg/l

CK

Ref: 35-210 U/l

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Myocardial Cells

![Graph showing CKMB levels over days for different patients and the median CKMB.]

- **Ref:** < 4.0 µg/l
- **Axes:**
  - Y-axis: µg/l
  - X-axis: day
- **Lines:**
  - pt 1
  - pt 5
  - pt 2
  - pt 4
  - pt 3
  - pt 6
  - Median CKMB

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Liver function: ALAT-ASAT-Bilirubin
Median values in 6 patients

ALAT ASAT units/l
Bilirubin μmol/l

- Median ASAT
- Median ALAT
- Median Bili

day 1, day 2, day 3, day 4, day 5, day 6, day 7, day 8, day 9, day 10, day 11, day 12, day 13, day 14, day 15, day 16

Wanscher M, et al
Comparing blood samples in patients with and without circulatory arrest.

**Creatine Kinase**
- No arrest vs arrest
- Median values
- Ref: 35-210 U/l

**Myoglobin**
- No arrest vs arrest
- Median values
- Ref: 19-49 µg/l

**Creatinine**
- No arrest vs arrest
- Median values
- Ref: 50-90 µmol/L

**ALAT**
- No arrest vs arrest
- Median values
- Ref: 10-45 U/l
### Ustein style report of 14 victims.

**Victims #1-7 were recovered with circulatory arrest**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Body mass index (kg/m²)</th>
<th>Water temperature, °C</th>
<th>Duration to first EMS contact (min)</th>
<th>Glasgow coma scale</th>
<th>Airway intubation</th>
<th>Duration chest compression (min)</th>
<th>Core Temperature, °C</th>
<th>First recorded rhythm</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>15</td>
<td>Male</td>
<td>21.8</td>
<td>2</td>
<td>121</td>
<td>3</td>
<td>N</td>
<td>57</td>
<td>16.0</td>
<td>VF</td>
</tr>
<tr>
<td>#2</td>
<td>16</td>
<td>Male</td>
<td>18.4</td>
<td>2</td>
<td>121</td>
<td>3</td>
<td>N</td>
<td>56</td>
<td>20.2</td>
<td>VF</td>
</tr>
<tr>
<td>#3</td>
<td>15</td>
<td>Male</td>
<td>21.6</td>
<td>2</td>
<td>168</td>
<td>3</td>
<td>Y</td>
<td>65</td>
<td>18.4</td>
<td>Asystoli</td>
</tr>
<tr>
<td>#4</td>
<td>16</td>
<td>Female</td>
<td>17.3</td>
<td>2</td>
<td>153</td>
<td>3</td>
<td>Y</td>
<td>88</td>
<td>15.5</td>
<td>PEA</td>
</tr>
<tr>
<td>#5</td>
<td>15</td>
<td>Female</td>
<td>24.0</td>
<td>2</td>
<td>168</td>
<td>3</td>
<td>Y</td>
<td>58</td>
<td>19.4</td>
<td>VF</td>
</tr>
<tr>
<td>#6</td>
<td>16</td>
<td>Male</td>
<td>22.7</td>
<td>2</td>
<td>108</td>
<td>3</td>
<td>Y</td>
<td>120</td>
<td>17.5</td>
<td>VF</td>
</tr>
<tr>
<td>#7</td>
<td>17</td>
<td>Male</td>
<td>21.6</td>
<td>2</td>
<td>108</td>
<td>3</td>
<td>Y</td>
<td>125</td>
<td>20.0</td>
<td>Asystoli</td>
</tr>
<tr>
<td>Median (range)</td>
<td>16 (15-17)</td>
<td></td>
<td>21.1 (17.3-24.0)</td>
<td></td>
<td>121 (108-169)</td>
<td>3</td>
<td></td>
<td>65 (56-125)</td>
<td>18.4 (15.5-20.2)</td>
<td></td>
</tr>
</tbody>
</table>
EEG was performed:

Day 3 and 4 6 patients
Day 6 and 7 3 patients
Day 11 1 patient

No electrographic status epilepticus or epileptiform activity
CTC and MRI
Representative example of hyperintensities on magnetic resonance in basal ganglia
Days on the ventilator (median/range): 6 (2-15)
All 7 survive
Hospital LOS: 10 – 17 days

All 7 transferred to Hammel Neuro Rehabilitation Centre with various signs of damage to central and peripheral nerve functions

CPC at discharge:
CPC 1-2: 4 patients (2 males, 2 females)
CPC 3-4: 3 patients (3 males)
Figure 2. Representative example of hyperintensities on magnetic resonance in basal ganglia that resolved at 6 months follow-up.
Table 3
Results of proton magnetic resonance spectroscopy at baseline and at follow-up in the seven patients with initial circulatory arrest.

<table>
<thead>
<tr>
<th></th>
<th>Baseline (n = 7)</th>
<th>Half year follow-up (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parietal white matter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAA/tCr decreased</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>tCho/tCr decreased</td>
<td>0</td>
<td>4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>ml/tCr increased</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Lip + MM</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Occipital gray matter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAA/tCr decreased</td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>tCho/tCr decreased</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>ml/tCr increased</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lip + MM</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Nucleus lentiformis gray matter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAA/tCr decreased</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>tCho/tCr decreased</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>ml/tCr increased</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Lip + MM</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Typical abnormalities after insults are counted. Decreased N-acetylaspartate to total creatine ratio (NAA/tCr) suggest neuronal damage or dysfunction, elevated total choline to total creatine ratio (tCho/tCr) signifying loss of membrane integrity, elevated myo-Inositol to total creatine ratio (ml/tCr) suggest gliosis, and elevated lipids and macromolecules (Lip + MM) indicating necrosis.

<sup>a</sup> Median 29% increased, range 12–40% increased.
<sup>b</sup> Median 20% decreased, range 16–25% decreased.
Clinical paper

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

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ABSTRACT

Background: Resuscitation guidelines for the treatment of accidental hypothermia are based primarily on isolated cases. Mortality rates are high despite aggressive treatment aimed at restoring spontaneous circulation and normothermia.

Methods: The present report is based on a boating accident where 15 healthy subjects (median age 16 years) were immersed in 2°C salt water. Seven victims were recovered in circulatory arrest with a median temperature of 18.4°C (range 15.5–20.2°C). They were all rewarmed with extracorporeal membrane oxygenation (ECMO) and were subsequently evaluated with advanced neuroradiological and functional testing. The remaining 7 had established spontaneous circulation without the use of ECMO. One victim drowned in the accident.

Results: The victims that survived the accident without circulatory arrest were predominantly females with a higher body mass index. Victims with circulatory arrest till on arrival was a median of 6.61 (range 5.43–6.94), with ECMO being established a median of 226 (178–241) min after the accident. Magnetic resonance spectroscopy showed neuronal dysfunction in five. In five victims initial normal white matter spectra progressed to show evidence of abnormal axonal membranes. Based on the seven-level Functional Independence Measure test functional outcome was good in six circulatory arrest victims and in all without circulatory arrest. Mild to moderate cognitive dysfunction was seen in six and severe dysfunction in one circulatory arrest victim.

Conclusion: Seven patients with profound accidental hypothermic circulatory arrest were successfully resuscitated using a management approach that included extracorporeal rewarming, followed by successive periods of therapeutic hypothermia and sedated normothermia and intensive neurorehabilitation. Seven other hypothermic victims (core temperature as low as 23°C) that did not suffer circulatory arrest also survived the accident.

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Profound hypothermia, defined as a core temperature of less than 30°C is associated with a significant risk of circulatory arrest. Even with aggressive treatment including circulatory support and rewarming mortality rates due to progressive uncontrollable systemic oedema, pulmonary insufficiency and cerebral oedema is high. Successful management of deep hypothermia with restoration of circulation and normal body temperature has been achieved using extracorporeal membrane oxygenation (ECMO) in selected victims. However, the understanding and management of accidental deep hypothermia has been largely based on isolated retrospective cases and reviews, whereas data based on controlled studies are not available for obvious ethical reasons.

The present report is based on a boating accident that occurred in February 2011 where a dragon boat carrying 13 teenagers and 2 adult teachers from a continuation high school capsized on a fjord.