Submersion injuries

Drowning
Near drowning
Outline

- Epidemiology.
- Definitions.
- Pathophysiology.
- Sign and symptom.
- Management.
- Prevention.
- Prognosis.
INTRODUCTION

- Drowning accounts for at least 150,000 deaths per year worldwide.
- Drowning is 2ed cause of death in 1-14 yr age group.
- Approximately 1:8 Male and 1:23 Females experience some form of water-associated event.
- 7% of these incidents related to child abuse or neglect (US).
- For every one mortality there is 4 hospitalization.
- 2.5-4.6% of drowning victims had pre-existing seizure disorder.
50% of drowning in the swimming pools

- Swimming pool: 49%
- Bathtub: 14%
- Other water: 37%
Definition of Drowning

Near-drowning:

survival, at least temporarily, after 24h of submersion:

- Aspiration of fluid into the lungs. ("Wet Near-Drowning")
- Asphyxia secondary to laryngospasm. ("Dry Near-Drowning")
Definitions of Drowning

After World Congress on Drowning 2002

**Drowning:** is a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium (regardless of the outcome).

AHA suggests:

Term **drowning** should refer to death within 24 hrs

Term **submersion injury** should be used up until the time of drowning-related death.
Classification

According to water Temperature:
Warm-water drowning occurs at water Temp of 20°C or higher.
Cold-water drowning occurs at water Temp less than 20°C.
Very-cold-water drowning, occurs at water at Temp of 5°C or less.

According to water content:
Freshwater submersion injury.
Salt-water submersion injury.
Drowning Causes by Age

In infants younger than 1 year:
Bathtubs and buckets.
Child abuse should be considered.

In children aged 1-5 years:
Swimming pools are the most common.

In young adults aged 15-19 years:
Ponds, lakes, rivers, oceans most common venue.
Injuries are frequently associated with boating, alcohol, or both.
RISK FACTORS

- Inability to swim or overestimation of swimming capabilities.
- Risk-taking behavior.
- Use of alcohol and illicit drugs.
- Inadequate adult supervision.
- Seizure disorder.
- Concomitant trauma.
ARRHYTHMIA AS A RISK FACTOR

May be a more common cause of drowning than appreciated.

Cold water immersion and exercise can cause fatal arrhythmias in patients with the congenital long QT.

Mutations in the cardiac ryanodine receptor (RyR)-2 gene, associate with VT, have been identified in some unexplained drowning
Hyperventilation prior to a dive

- Reduce (PaCO2)
- (CaO2) not increase appreciably

swimming

(PaO2) falls to 30 to 40 mmHg before the PaCO2 rises sufficiently to trigger breathing

cerebral hypoxia, seizures, loss of consciousness

drowning
Submersion

Apnea, air hunger, and a struggling by the reflex inspiratory efforts.

laryngospasm (dry drowning) 10-15%.

Aspiration (wet drowning)

Hypoxemia

Organs dysfunction

Ongoing pulmonary injury, reperfusion injury, or multiorgan dysfunction
Salt vs Fresh water

Theoretically:

* Salt water causes plasma to be drawn into the lungs, leading to massive pulmonary edema.

* Fresh water leads to volume overload and dilutional effects on serum electrolytes.
The Fact 😊

* Most patients have fluid aspiration of less than 4 mL/kg.
* Aspiration of 11 mL/kg is required for alterations in blood volume to occur.
* Aspiration of 22 mL/kg is required before significant electrolyte changes develop.

the distinction between the two is only considered in unusual media
END ORGAN EFFECTS

Hypoxemia produces tissue hypoxia, which affects all tissues and organs within the body.
Neurological System

- The major determinant of survival and morbidity.

- Prolonged hypoxia are likely to lead to both significant primary and secondary injury.

- Secondary Injury:
  Multi-factorial, and it is the scope of our care.
Secondary Injury

- Reperfusion.
- Acidosis.
- Cerebral edema.
- Hyperglycemia.
- Release of neurotransmitters.
- Seizures.
- Hypotension.
- Impaired cerebral autoregulation.
Hypoxia

Increase ICP

Displace CSF
Decrease CBF
Displace brain tissue

Acidosis

Clinical manifestation
Pulmonary

ARDS

P. infection

ARDS Of AW

Bronchi Spasm

Changes in surfactant

Atelectasis

Occlusion Of AW

Dead space

R to L shunt

PHT

VALI
The clinical presentations of submersion injuries

- Death
- CPA
- Asymptomatic
- Symptomatic
Asymptomatic

- Brief submersion.
- Submersion with immediate resuscitation.
Symptomatic

- Cough.
- RD.
- Wheezing.
- Hypothermia.
- Bradycardia or tachycardia.
- Vomiting, diarrhea, or both.
- Anxiety.
- Altered mental status.
MANAGEMENT

- Prehospital care.
- Emergency unit care.
- Inpatient care.
1- Pre-hospital care

- Remove from water as soon as possible.
- The Heimlich maneuver has not been shown to be effective.
- Assesses the need for CPR.
- Apply the BLS recommendation.
- Neck should be supported in a neutral position.
1- Pre-hospital care

- Pulses may be difficult to palpate in hypothermic patient.
- High flow oxygen to the spontaneously breathing patient.
- Apnea → intubate or ventilate effectively with BMV.
- High pressures may be required for BMV.
- Attempt rewarming all hypothermic patients (Temp <33°C).
2- Emergency Department Management

- Prehospital resuscitative efforts should continue.
- Evaluate the patient for skeletal and internal injuries.
- Remove wet clothes and rewarm hypothermic patients.
- Resuscitative efforts should continue until the temperature is 35°C.
Triaging Submersion Injury

75 evaluable patients, 3 were directly admitted to the inpatient service with no documented initial medical evaluation reported in the medical record. Of the remaining 72 patients, 62 (86%) were symptomatic at the time of the initial medical evaluation in the emergency department; 10 patients (14%) were asymptomatic. Seventy percent of the initially asymptomatic patients and 57% of patients who were symptomatic at the time of initial medical evaluation were asymptomatic by 8 hours after the submersion event. By 18 hours postsubmersion, all patients who were initially asymptomatic and 72% of initially symptomatic patients were normal. Thirty-five percent and 80% of patients who had abnormal initial physical examinations and abnormal chest x-rays had a normal physical examination by 8 hours and 18 hours, respectively, and all remained normal.

CONCLUSIONS:

*Routine hospital admission of all children who have had immersion accidents is unnecessary.*

*All who ultimately developed symptoms did so within 7 hours of immersion.*

AD Department of Pediatrics, University of Texas Southwestern Medical Center, Dallas 75235, USA. PMID8784358
3- Inpatient management:

Supportive care.

and

Treatment of organ specific complications.
Neurologic injuries

The goal is to prevent secondary neurologic injuries due to:

- Ongoing ischemia.
- Cerebral edema.
- Hypoxemia.
- Fluid and electrolyte imbalances.
- Acidosis.
- Seizure activity.
$$\text{CPP} = \text{MAP} - (\text{ICP or CVP})$$

(whichever is higher)

![Diagram of normal intracranial contents](Fig 1a)
Keep CPP > 40-50 mm Hg in children.

- MBP should be monitored to restore good CPP and CBF.
- Volume depletion should be avoided.
Mild hyperventilation: maintain a PaCO2 of 35-40.

Excessive hyperventilation should be avoided.
Neurological injuries

- The head of the bed should be elevated approximately 30 to 35.
- Diuretics should be used to avoid hyper-volemia and
- Mannitol can be used with high ICP if Osmolality <320 mOsm/L.
- 3% NaCl can be used with tolerating Osmolality of 360 mOsm/L.

[CRITICAL CARE MEDICINE; Toung,TJ; 33(1):203-208 (2005)]
[ANESTHESIOLOGY; Rozet,I; 107(5):697-704 (2007)]
Neurological injuries

- Seizure activity should be aggressively controlled.
- Phenytoin is the preferred anticonvulsant.
- Neuromuscular blocking agents should be avoided.
- Euglycemia should be meticulously maintained.
- Hyperthermia should be avoided.
ICP monitoring may not change outcome, just predict it.
Treatment of Hypothermia

- **Hemodynamically stable patients**
  - Rewarm using warmed humidified inspired gases, warmed IV fluids, heating blankets, warm air surface mechanisms.

- **Hemodynamically unstable patients**
  - Rewarm using the above plus bladder irrigation, gastric and pleural lavage, peritoneal or hemodialysis with warmed fluids and Cardiopulmonary bypass (CPB)

**Hypothermia can not render a protective effect if it is preceded by hypoxemia**
Hypothermia Debate:

Dramatic recoveries following icy water drownings are well documented despite prolonged resuscitation.

Although more investigations are needed, the maintenance of hypothermia to 32-34 for 12 to 24 hours is a reasonable therapeutic in comatose children AHA.
Table 59.4 Evidence in support of the use of therapeutic hypothermia (32â€“34Â°C for 12â€“24 hrs) immediately after resuscitation from cardiac arrest

<table>
<thead>
<tr>
<th>Evidence (references)</th>
<th>Level*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two prospective, randomized studies of adults with VF arrest (18,95)</td>
<td>1,2</td>
</tr>
<tr>
<td>Two prospective, randomized studies of newborns with birth asphyxia (50,128)</td>
<td>2</td>
</tr>
<tr>
<td>Numerous animal studies of both asphyxial and VF arrest (146)</td>
<td>6</td>
</tr>
<tr>
<td>Acceptable safety profiles in adults (18,95) and neonates (50,128) treated with hypothermia for up to 72 hrs</td>
<td>7</td>
</tr>
</tbody>
</table>

*Level 1: Randomized clinical trials or meta-analysis of multiple clinical trials with substantial treatment effects
Level 2: Randomized clinical trials with smaller or less significant treatment effects
Level 3: Prospective, controlled, nonrandomized cohort studies
Level 4: Historic, nonrandomized cohort or case-controlled studies
Level 5: Case series: patients compiled in serial fashion, control group lacking
Level 6: Animal or mechanical model studies
Level 7: Extrapolations from existing data collected for other purposes, theoretical analyses
Level 8: Rational conjecture (common sense); common practices accepted before evidence-based guidelines

Adapted from The International Liaison Committee on Resuscitation (ILCOR) Consensus on Science with Treatment Recommendations for Pediatric and Neonatal Patients: Pediatric basic and advanced life support. Pediatrics 2006;117:e955â€“77.
Hypothermia:

Effects of Hypothermia:

- **Arrhythmias**
  
  A core temp <28c can induce VFib, which may be refractory to defib until temp has been raised.

- **Coagulopathy.**

- **Impaired immune function.**

- **Reduced myocardial function.**

- **Acidosis.**

- **Electrolyte abnormalities.**
Figure 59.9. Futuristic treatment strategies targeting cell-death pathways (apoptosis, necrosis, and/or autophagy) that produce hypoxic-ischemic encephalopathy. The therapeutic windows for these novel strategies are likely temporally and regionally dependent.
Respiratory treatment

**Bronchospasm:**

is often seen in near-drowning victims and management is treated similarly to acute asthma.

**Steroids:**

There is little evidence to support the routine use steroids.
Respiratory treatment

Antibiotic

- There is little evidence to support the routine use of AB.
- AB indicated in clinical infection or if the victim was submerged in grossly contaminated water.
- If pneumonia follows near-drowning, a high suspicion for Aeromonas, Pseudomonas, and Proteus must be maintained.
Mechanical Ventilation Strategy

Similar to those employed in other types of acute lung injury.

- Use PEEP, CPAP, BIPAP.
- Lower TV 6ml/kg.
- Avoid Volutrauma, Barotrauma and Oxygen toxicity.
- Early use of HFOV, APRV.
- Permissive hypercapnea….?.

*It is contraindicated if intracranial hypertension is suspected.*

- ECMO for refractory hypoxemia.
Respiratory treatment  cont

**Surfactant:**

*The idea replacing surfactant that has been washed out.

*However, clinical and animal studies have not recommended for this indication.
Homodynamic support

- Hypothermia
- Vasoconstriction
- Blood moves to the core
- Hypotension
- Volume receptors sense fluid overload
- Increased permeability
- Myocardial dysfunction
- Re-warming
- Hypoxia
- Arrhythmias
- Decreased ADH
Hemodynamic support

Treatment

- Restore good intravascular volume
- Use inotropic support
Figure 59.7. Algorithm for the management and treatment of post-circulatory arrest syndrome in infants and children. Guidelines based on medical literature and protocols and practice at the Children's Hospital of Pittsburgh. CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; ECPR, extracorporeal cardiopulmonary resuscitation; EEG, electroencephalogram; ICP, intracranial pressure; CBF, cerebral blood flow; EKG, electrocardiogram.
Prognosis:

- 15% of children admitted for drowning die in the hospital.
- 20% of survivors suffer severe, permanent neurological disability.

Neurological disability:

- Minimal brain dysfunction.
- Spastic quadriplegia.
- Extrapyramidal syndromes.
- Optic and cerebral atrophy.
- Peripheral neuromuscular damage.
Prognosis

- Number of neurologically impaired survivors increasing as the care of other complications improves.

- No good early predictors of poor neurologic outcomes.

- Survival of cardiac arrest post submersion better than other causes 32% to 7% in one study.

Prognosis

Poor Prognosis:

- Duration of submersion >10 minutes.
- Time of effective CPR > 10 min.
- GCS< 5.
- Age < 3 y.
- PH at presentation < 7.1.
- Water temperature > 10 c.
- The lack of spontaneous, purposeful movements at 24 hours is an ominous sign.
In one study all of 44 children with near-drowning whom had no spontaneous movement after 24h did or suffered severe neurological sequels.

continued CPR on arrival to the hospital associated with 35-60% mortality and 60-100% long-term neurologic squeals in survivor.
Near-drowning is preventable in most cases
PREVENTION  cont

1-gating and fencing of swimming pools decrease swimming pool drownings by 80%.
PREVENTION

2- Adequate adult supervision.
PREVENTION cont

3-Swimming with a partner.
PREVENTION

4- Appropriate use of personal flotation devices.
PREVENTION cont

5- Avoidance of alcohol and illicit drugs while swimming or boating.
PREVENTION

6- Warn the parents that toddlers can drown in shallow areas, including toilets and buckets of water.
Summary

- Drowning is the 2nd cause of death in 1-14 y.
- Arrhythmia and SD are risk factor.
- Hypoxemia produces tissue hypoxia, which affects all organs.
- Neurological injury is the major determinant of survival and morbidity.
- Application of BLS recommendation is cornerstone.
- The goal is to prevent secondary neurologic injuries by maintaining CBF and CPP.
- For MV Apply lung protective strategy but avoid permissive hypercapnea.
Summary cont

- Maintain a PaCO2 of 35-40 and avoid severe hyperventilation.
- Mannitol and 3%NaCl can be used with high ICP.
- ICP monitoring may not change outcome, just predict it.
- Although more investigation is needed. Maintenance of hypothermia to 32-34 for 12 to 24 hours is a reasonable.
- There is little evidence to support the routine use of steroids.
- There is little evidence to support the routine use of AB.
- Near-drowning is preventable in most cases.
Thank you