Chapter 9: Submersion

Submersion

This chapter will train you to treat health conditions caused by accidental submersion in water and methods to prevent this type of injury. Objectives:

- Be able to define the basic terms of drowning, near-drowning, and submersion injury.
- Be able to describe the mechanism of shallow water blackout.
- Be able to describe the basic pathophysiology of submersion injury.
- Be able to describe the effects of submersion injury on the pulmonary system.
- Be able to describe the initial management of a victim of a submersion injury in the wilderness setting.
- Be able to describe the basic hospital management of the submersion victim.
- Be able to describe which patients require evacuation to a medical setting.
- Be able to describe methods to prevent submersion injury.
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Case 1

An eighteen year-old male falls out of a raft in a class IV rapid and is pulled under the water repeatedly as he fights his way through the rapids. He is pulled out of the water on the shore and is awake and alert. He is coughing vigorously and complains of shortness of breath and a full sensation in his chest. His past medical history is unremarkable. Vital signs: P = 108, RR = 26, BP = 126/88. Physical examination is remarkable for obvious respiratory distress with retractions and rales bilaterally throughout his lungs. The remainder of his examination is normal.

1. What is the next step in the management of this patient?
2. Are there any other vital signs you would be interested in obtaining in this patient, if possible?
3. Are there any medications you could treat him with that you would normally carry with you?
4. Does he require evacuation to a hospital or can he stay in the backcountry with observation?

Case 2

You are at a campsite by a lake and you hear a cry for help. A father is holding his two year-old son who is crying. According to the father, he was in the shallow water of the lake with his child and he turned his head away for “just a couple of seconds”. When he turned back, he noticed his son was under the water and not moving. He immediately grabbed his son who started crying. There was no color change. The child is alert and crying. Vital signs: P = 108, RR = 20. Physical exam is normal to include normal respiratory efforts and a normal pulmonary exam.

1. What is your next step in the management of this child?
2. Are there any other vital signs you would be interested in obtaining?
3. Does this child require evacuation to a hospital or can he stay at the campsite with observation?
4. If you elect to observe this child, what is the time interval you should observe him?
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Background

Terminology

- **Drowning** – Death by suffocation after submersion in a liquid medium.
- **Near Drowning** – Survival for at least 24 hours after a submersion episode. If the patient subsequently dies of complications after 24 hours (due to pneumonia, ARDS, cerebral edema, etc.), the cause of death is attributed to that complication and is referred to as secondary to near drowning.
- **Delayed or Secondary Drowning** – Refers to the pulmonary complications manifest in the Adult Respiratory Distress Syndrome (ARDS), often seen after submersion incidents.
- **Submersion Incident** – The preferred nomenclature given to the situation when a person is adversely affected by being submerged in water. This term is descriptive, implies no particular prognosis, and is inclusive of both drowning and near drowning.
- **Wet Drowning** – A submersion incident with aspiration of water into the lungs with resultant pulmonary damage. This occurs in approximately 85% to 90% of victims.
- **Dry Drowning** – A submersion incident without significant aspiration of water into the lungs. This occurs in approximately 10% to 15% of victims.
- **Shallow Water Blackout** – A special cause of submersion injury that occurs in people who hyperventilate before entering the water for an underwater swim. Hyperventilation significantly reduces the PaCO₂ without increasing oxygen storage. The vigorous underwater activity uses the available oxygen, causing hypoxemia, but before sufficient CO₂ accumulates to provide a stimulus to return to the surface. The patient loses consciousness due to the hypoxemia and drowns.

Epidemiology

- Drowning is 2 nd only to motor vehicle accidents as the most common cause of accidental death.
- Annually in the US, there are an estimated 80,000 submersion incidents with 9,000 deaths.
- Annually in the world, there are an estimated 150,000 deaths due to submersion.
- Drowning mainly kills the young
  - 64% of all victims are younger than 30 years old
  - 26% of all victims are under age 5
  - There is a bimodal age distribution in the young with large numbers of deaths in children age 4 and younger and then later in teenagers
- Freshwater drowning, especially in pools, is more common than saltwater drowning. This includes coastal areas.
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- Risk factors:
  - Age: toddlers and teenage boys
  - Location: home swimming pools
  - Gender: males predominate in all age groups
  - Race: black children are most at risk
  - Drugs: particularly alcohol
  - Trauma: secondary to diving, falls, and horseplay

Pathophysiology

General

The basic pathophysiology of submersion injury is respiratory failure with hypoxemia and resultant cardiac ischemia and neurologic injury.

- Older victims who are not immediately unconscious may initially panic and struggle in the water. They will hold their breath or hyperventilate and try to stay above the water surface.
- Breath holding may be attempted. At some point a break point is reached and the body will involuntarily (reflexively) breathe, even if the victim is under water. This point is determined by the both $\text{Pa}_2\text{O}_2$ and $\text{Pa}_2\text{O}_2$.
- At this point of involuntary breathing, aspiration and vomiting occurs with an impact on at least the pulmonary system.
- Regardless of the type of drowning (wet or dry drowning) the patient will have a similar outcome. There is no evidence to support the assumption that a dry drowning would result in a better outcome.
- The final common pathway is pulmonary injury with profound hypoxemia. The resuscitation depends more on the reversal of hypoxemia than on the type of submersion injury.

Freshwater Versus Saltwater Submersions

- At one time, based on animal studies, it was believed that different pathologic pathways existed between drowning in fresh and salt water.
- It was theorized that with freshwater submersion the aspirated water is hypotonic and would rapidly pass through the lungs going into the intravascular compartment. This would create fluid overload and a dilutional effect on serum electrolytes.
- With saltwater aspiration, it was theorized that the hypertonic saltwater would cause fluid to be drawn into the alveoli. Thus creating massive pulmonary edema and hypertonic serum.
- In reality, patients who survive a submersion incident do not aspirate enough volume to cause hemodilution or electrolyte changes. Based on the animal studies, it required an aspiration of at least 22 ml/kg whereas the typical human aspirates less than 10 ml/kg.
- The one exception is the Dead Sea, which is extremely hypertonic. In surviving submersion victims, significant effects on serum calcium and magnesium have been observed.

Organ System Effects

Pulmonary

- The lung is the target organ of injury.
- Aspirated water evokes vagally mediated pulmonary vasoconstriction and pulmonary hypertension.
- Aspirated water also has a significant effect on lung compliance and recoil due to the washing out and destruction of surfactant. This leads to atelectasis and stiff, noncompliant lungs.
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- All of these effects lead to significant ventilation-perfusion mismatching as well as a diminished oxygen diffusing capacity. This may result in relative or significant hypoxemia, depending on the extent of the pulmonary injury.
- Clinical symptoms
  - Shortness of breath
  - Air hunger
  - Cough
  - Rales, rhonchi, and wheezing

Cardiovascular

- Cardiac dysrhythmias are common and significant in submersion incidents but are usually secondary to the hypoxemia or acidosis, but are not primary in etiology.
- It is unlikely that the dysrhythmias are caused by electrolyte disturbances.

Central Nervous System

- 12% to 27% of near-drowning victims sustain neurologic damage.
- Insults to the CNS usually result from the hypoxia and/or trauma to the brain or spinal cord.
- If the patient has an altered mental status, appropriate evaluation must look for CNS trauma as a source and not ascribe the symptoms to the hypoxia.
- Be concerned for cervical spine injuries when victims have been diving in pools or waters of unknown depth.

Electrolytes and Blood Volume

- These are usually unaffected by the aspiration with the exception of the Dead Sea submersion victims.
- Coagulopathy is uncommon and if it occurs it is usually due to prolonged or severe hypoxemia.

Renal

- Renal failure is uncommon but acute tubular necrosis may occur after prolonged hypoxemia.

Treatment

First Aid

- Rapid but cautious rescue so that the rescuers do not become victims.
- The gold standard is immediate and aggressive initiation of ventilation and oxygenation.
- Always consider coexistent trauma and institute spinal protections if there is any concern.
- If possible, measure blood oxygenation with a pulse oximeter.
- Administer 100% oxygen if it is present.
- If the patient is unable to maintain his or her airway, then intubate if possible
- CPR should be started on any patient with even a remote possibility of success.
- There are no special drainage procedures to “empty” water out of the lungs or stomach.
- The Heimlich maneuver was at one time recommended by the American Red Cross and American Heart Association. However, this technique has been criticized and now this maneuver is not recommended.
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Hospital Care

- The focus is on treatment of respiratory failure and evaluation for associated injuries.
- The usual ABCs and safety net apply (IV, O₂ monitor, pulse ox).
- Adequate oxygenation must be ensured.
- Bronchospasm is treated with albuterol.
- Some patients in respiratory distress may benefit from CPAP if they can tolerate it. However, this has not been studied.
- Endotracheal intubation if the patient is unable to maintain their airway or has a \( P_aO_2 \) of less than 60 on 100% oxygen.
- If intubated, PEEP at 5 – 10 cm H₂O should be used.
  - It will decrease the amount of intrapulmonary shunting.
  - It will decrease ventilation-perfusion mismatch.
  - It will increase the functional residual capacity.
- CXR should be obtained in all patients
  - The findings may show noncardiogenic pulmonary edema, perihilar infiltrates, fine alveolar infiltrates or be completely normal
  - An initially normal CXR does not rule out significant pulmonary insult.
- Cervical spine radiographs should be obtained if there is concern of spinal injury.
- Nasogastric tube may help empty the stomach.
- Patient with ongoing CPR
  - Those patients who are undergoing CPR who sustained a cold water submersion or have a rectal temperature of less than 30° to 32.5° C (86° to 90.5°F) should be warmed to these temperatures before the resuscitation is terminated.
  - Those patients who are normothermic or a victim of warm water submersion, and have CPR ongoing for 30 minutes or more without success may have the CPR terminated.
- There is no role for prophylactic antibiotics.
- There is no role for prophylactic steroids.
- There is a question whether surfactant given through the ET tube may be beneficial. However, this management technique has not been formally studied.

The Asymptomatic Patient

- These patients arrive in the ED with no evidence of a submersion incident.
- In addition to the history and physical exam, one should evaluate these patients with a CXR and a pulse oximetry at a minimum.
- If everything is normal, observe the patient for 6 hours.
- If there is no change and the patient remains asymptomatic, then the patients may be discharged to home. Appropriate precautions and 24-hour follow-up are recommended.

Prognosis

Statistics on survival and the incidence of severe neurological deficits after near drowning are difficult to interpret.

- Unfavorable prognostic factors:
  - Age 3 years and younger
  - Estimated submersion time longer than 5 minutes
  - No resuscitation attempts for at least 10 minutes after rescue
  - Patient in a coma on ED admission
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- Arterial blood gas pH 7.1 or less
  - With two or less of these factors present, there is a 90% chance of recovery.
  - The presence of three or more of these factors reduces the chance of survival to less than 5%.

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**Army Doctor Rescues Drowning Hiker**

*Soldiers Radio and Television*

He just wanted to get away. Army doctor Lt. Col. Peter Weina had just finished a rough week at Walter Reed Army Medical Center and at home with his 2-month-old son. A weekend of kayaking on the Class 5 rapids just north of Washington, D.C., was just what the doctor ordered for himself.

Little did Weina imagine that on Aug. 5, both his kayaking and medical skills would combine to save a life.

The white-water rapids Weina chose to navigate are considered among the most challenging on the Eastern Seaboard. "The river at this point goes through kind of a gorge, and there are hikers along the top of the shoreline," Weina said. "And all of a sudden everybody's hollering and screaming and yelling and waving their arms. And I knew it wasn't because of my expert paddling."

Weina looked upstream and saw that one of the hikers had fallen into the river and was fighting for his life. He maneuvered his kayak into the middle of the rapids and was able to grab the hiker as he swept by.

"We were just trying to ride out the rapids at first, and then what I did was to get him over to the shoreline as quickly as I could so I could check him out," Weina said.

Other than a few bruises and near total exhaustion, the hiker was OK. Weina turned him over to Montgomery County, Md., Fire and Rescue Service officials and headed back up the river in his kayak.

"I'm a military physician 24 hours a day … whenever my patients need me, whether they're planned ones or not," Weina said of the experience.

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**Evacuation Guidelines**

- Evacuate those patients with an accidental submersion who suffered a loss of consciousness, required resuscitation, have difficulty breathing, tachypnea, hypoxemia (if measured) or a history of lung disease.

- Those patients who are asymptomatic with no respiratory distress may be observed for a period of at least six hours for development of new respiratory symptoms. If they are asymptomatic for this entire period, then they do not require evacuation.
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Prevention

- Prevention is more important than almost any action that one can take after a submersion incident has occurred.
- Alcohol should be avoided when participating in or supervising water activities.
- Everyone on a boat should always wear approved personal flotation devices that will support the person’s head above water, even if the person becomes unconscious.
- Camp far enough away from water so that people, especially children, do not accidentally wander into the water at night.
- Anyone who works on or near the water should have swimming, rescue, and life-saving skills.
- Young children should always be supervised when around water.
  - The one-minute phone call or other distraction is all that it takes for a child to become submerged.
  - Toddlers have drowned in toilets and small buckets of water.
  - Toddlers have drowned in bathtubs when left alone with older siblings to watch them with no adult supervision.
- Swimming pools:
  - These should be completely enclosed by a 5-foot fence with self-closing and self-latching locks.
  - This fence should also separate the pool from the house. This means that the pool should not be directly open to the back door of the house.
  - Appropriate life-saving equipment such as a pole to pull people to the side and life preservers should be near the pool.
  - Owners of swimming pools should be trained in CPR.
  - Children in families who have a pool should have swimming lessons early.
- Patients with seizure disorders should always be supervised if swimming and should probably bathe in showers.

Questions

1. Which one of the following is the mechanism behind shallow water blackout?
   a. Hyperventilation results in an increased blood oxygen level, causing one to lose the drive to surface to breathe
   b. Hyperventilation results in an increased blood carbon dioxide level, causing one to lose the drive to surface to breathe
   c. The lowered carbon dioxide level from hyperventilation causes one to seize and lose consciousness under the water
   d. The oxygen level in the blood drops too low before one has the drive to surface to breathe
   e. Vigorous activity causes the carbon dioxide level to drop while under the water

2. Which one of the following describes the basic pathophysiology of submersion injury?
   a. Cerebral edema due to excessive fluid intake and resultant respiratory arrest
   b. Electrolyte dilution resulting in cardiac dysrhythmia and respiratory arrest
   c. Pulmonary injury resulting in hypoxia and possibly cardiac and neurologic injury
   d. Increased compliance and elasticity of the lungs leading to hypoxia
   e. Respiratory difficulty due to pneumonia caused by bacteria in the aspirated water
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3. A 30 year-old male dives off a cliff into a lake. He surfaces within 10 seconds but is floating and appears unconscious. Which one of the following is the most likely etiology for his symptoms?
   a. He aspirated a large amount of water when he went into the water and became hypoxic
   b. He hyperventilated before jumping in the water and suffered and arrest due to an increased blood carbon dioxide level
   c. He suffered a cardiac arrest due to the suddenness coldness of the water
   d. He suffered a cardiac arrest due to aspiration of hypotonic water and electrolyte dilution
   e. He suffered a cervical injury with paralysis by striking the bottom of the lake

4. Which one of the following is not part of the management of the submersion victim in the field setting?
   a. Heimlich maneuver to increase gastric emptying
   b. Immediate CPR if the patient is not breathing
   c. Scene assessment to ensure the area is safe to rescue the victim
   d. Stabilization of the cervical spine if there is concern of injury
   e. Thorough assessment of the respiratory system if the patient is awake

5. Which one of the following is not a method to help prevent submersion injury?
   a. All rafters should wear personal floatation devices
   b. Alcohol should be consumed in moderation when around the water
   c. Camp sites should be established far away from water, especially when children are present
   d. Swimming pools should be surrounded by a five-foot fence
   e. Those working around or on water should have CPR and water rescue skills

Answers:
1. d
2. c
3. e
4. a
5. b