Effects of drowning on the body

According to the new definition adopted by the WHO in 2002, Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid. Drowning is defined as death from asphyxia that occurs within the first 24 hours of submersion in water. Near drowning refers to survival that lasts beyond 24 hours after a submersion episode. Hence, it connotes an immersion episode of sufficient severity to warrant medical attention that may lead to morbidity and death. Drowning is, by definition, fatal, but near drowning may also be fatal. (2)

Drowning is the seventh leading cause of accidental death in the United States. Though the exact incidence in India can only be a crude estimate, one keeps coming across incidences of drowning fatalities. Many boating accidents lead to fatalities, possibly due to concomitant accidental injuries or trapping in submerged boat. Motor vehicle accidents with a fall in streams or ponds are also being reported with similar settings.

Drowning can also occur in scuba divers but may be associated with cardiac event or arterial gas embolism. Other possibilities to be kept in mind include hypothermia, contaminated breathing gas, oxygen induced seizures.

Even community swimming pool and home bathtubs and buckets are known to be adequate for young children to drown accidentally. Majority of such events are due to unsupervised swimming, esp in shallow pools or pools with inadequate safety measures. One look for features of closed head injury or occult neck fractures while management of such cases. Intentional hyperventilation before breath-hold diving is associated with drowning episodes.(3)

Weak swimmers attempting to rescue other persons may themselves be at risk of drowning. Males are more likely than females to be involved in submersion injuries. This is consistent with increased risk-taking behavior in boys, especially in adolescence.(4)

CAUSES OF DROWNING

- Alcohol consumption, which impairs coordination and judgement
- Failure to observe water safety rules e. g. having no life preserver or unsupervised swimming.
- Sustaining a head and neck injury while involved with a water sport
- Boating accidents
- Fatigue or exhaustion, muscle and stomach cramps
- Diving accidents including scuba diving
- Medical event while in the water e. g. seizure, stroke, and heart attack
- Suicide attempt
- Illicit drug use
- Incapacitating marine animal bite or sting
- Entanglement in underwater growth

Drowning and near-drowning events must be thought of as primary versus secondary events. Secondary causes of drowning include seizures, head or spine trauma, cardiac arrhythmias, hypothermia, syncope, apnea, and hypoglycemia.

PATHOPHYSIOLOGY

Drowning occurs when a person is submerged in water. The principal physiologic consequences of immersion injury are prolonged hypoxemia and acidosis, as a result of immersion in any fluid medium. The most important contribution to morbidity and mortality resulting from near drowning is hypoxemia and its consequent metabolic effects.

Immersion may produce panic with its respiratory responses or may produce breath holding in the individual. Beyond the breakpoint for breath-hold, the victim reflexly attempts to breathe and aspirates water. Asphyxia leads to relaxation of the airway, which permits the lungs to take in water in many individuals (‘ wet drowning’). Approximately 10-15% of individuals develop water-induced spasm of the air passage, laryngospasm, which is maintained until cardiac arrest occurs and inspiratory efforts have ceased. These victims do not aspirate any appreciable fluid (‘ dry drowning’). It is still controversial whether such a drowning occurs or not.(5)

Wet drowning is caused by inhaling large amounts of water into the lungs. Wet drowning in fresh water differs from salt water drowning in terms of the mechanism for causing suffocation. However, in both cases water inhalation leads to damage to the lungs and interfere with the body’s ability to exchange gases. If fresh water is inhaled, it passes from the lungs to the bloodstream and destroys red blood cells. If salt water is inhaled, the salt causes fluid from the body to enter the lung tissue displacing the air.

The pathophysiology of near drowning is intimately related to the multiorgan effects secondary to hypoxemia and ischemic acidosis. Depending upon the degree of hypoxemia and resultant acidosis, the person may develop cardiac arrest and central nervous system (CNS) ischemia. CNS damage may occur because of hypoxemia sustained during the drowning episode per se or may occur secondarily because of pulmonary damage and subsequent hypoxemia. Additional CNS insult may result from concomitant head or spinal cord injury.

Although differences observed between freshwater and saltwater aspirations in electrolyte and fluid imbalances are frequently discussed, they rarely of clinical significance for people experiencing near drowning. Most patients aspirate less than 4 ml/kg of fluid. 11 ml/kg is required for alterations in blood volume, and more than 22 ml/kg of aspiration is required before significant electrolyte changes develop. Regardless, most patients are hypovolemic at presentation because of increased capillary permeability from hypoxia resulting in losses of fluid from the intravascular compartment. Hyponatremia may develop from swallowing large amounts of fresh water.

The temperature of the water, not the patient, determines whether the submersion is categorized as a cold or warm drowning. Warm-water drowning occurs at a temperature greater than or equal to 20°C, cold-water drowning occurs in water temperatures less than 20°C, and very cold-water drowning refers to temperatures less than or equal to 5°C. Hypothermia reduces the person’s ability to respond to immersion, finally leading to helplessness or unconsciousness.

Pulmonary Effects

Aspiration of only 1-3 ml/kg of fluid can result in significantly impaired gas exchange. Fresh water moves rapidly across the alveolar-capillary membrane into the microcirculation. It causes disruption of alveolar surfactant, producing alveolar instability, atelectasis, and decreased compliance with marked ventilation/perfusion (V/Q) mismatching. As much as 75% of blood flow may circulate through hypoventilated lungs which acts as a shunt.

Salt water, which is hyperosmolar, increases the osmotic gradient, and therefore draws fluid into the alveoli. Surfactant washout occurs, and protein-rich fluid exudates rapidly into the alveoli and pulmonary interstitium. Compliance is reduced, alveolar-capillary basement membrane is damaged directly, and shunt occurs. This results in rapid induction of serious hypoxia.

Both mechanisms cause pronounced injury to the alveoli/capillary unit resulting in pulmonary edema. Fluid-induced bronchospasm also may contribute to hypoxia. Increased airway resistance secondary to plugging of the patient's airway with debris (vomitus, sand, silt, diatoms, or algae), as well as release of inflammatory mediators, result in vasoconstriction and reactive exudation, which impairs gas exchange. A high risk of death exists secondary to the development of adult respiratory distress syndrome (ARDS), which has been termed postimmersion syndrome or secondary drowning. Late effects include pneumonia, abscess formation, and inflammatory damage to alveolar capillary membranes. Postobstructive pulmonary edema following laryngeal spasm and hypoxic neuronal injury with resultant neurogenic pulmonary edema also may play roles.

Cardiovascular Effects

Hypovolemia is secondary to fluid losses from increased capillary permeability. Profound hypotension may occur during and after the initial resuscitation period. Ischemic metabolic acidosis due to lactic acid accumulation impairs cardiac function. This may often be a large component especially when the victim struggles violently trying to save himself. In addition, hypoxemia may directly damage the myocardium. Myocardial dysfunction result from ventricular dysrhythmias and asystole, decreasing cardiac output. Pulmonary hypertension may result from the release of pulmonary inflammatory mediators, which increase the right ventricular afterload, thus decreasing contractility.

CNS Effects

If hypoxemia and decreased cardiac output persists long enough, anoxic brain damage can ensue. Improvement in the management of pulmonary dysfunction caused by near drowning has left CNS injury the major determinant of subsequent survival and long-term morbidity.

Hypothermia

Thermal conduction of water is 25-30 times that of air. The temperature of thermally neutral water, in which a nude individual’s heat production balances heat loss, is 33°C. Physical exertion increases heat loss secondary to convection/conduction. A significant risk of hypothermia usually develops in water temperatures less than 25°C.

Other Effects

The clinical course may be complicated by multiple organ failure resulting from prolonged hypoxia. Disseminated intravascular coagulation, hepatic and renal insufficiency, metabolic acidosis, and gastrointestinal injuries must be considered and appropriately managed.

CLINICAL FEATURES (6)

History

All aspects leading to the submersion episode should be determined. Most patients are found after having been submerged in water for an unobserved period. Rarely does a patient present with the classic story of a novice swimmer stranded in water, frantically struggling and flapping arms in desperation. It is important to extract certain relevant factors in the beginning of resuscitative efforts, which include submersion time, associated trauma (especially cervical spine and head), drug or alcohol ingestion, type of water, degree of water contamination, water temperature, and response to initial resuscitation maneuvers.

Pertinent past medical history must be obtained to look for secondary causes of drowning, particularly trauma, seizures, cardiac disease, syncope, exhaustion, alcohol and drug use, hypothermia, diabetes mellitus, psychiatric history with suicidal tendencies or panic disorder, poor neuromuscular control such as severe arthritis or neuromuscular disorder.

Physical Examination

The clinical presentation of people who experience submersion injuries varies greatly. A victim of a submersion incident may be classified initially into one of the following four groups:

a) Asymptomatic

b) Symptomatic, manifesting with:

- Altered vital signs (eg, hypothermia, tachycardia, bradycardia)
- Anxious appearance

- Tachypnea, dyspnea, or hypoxia
- Metabolic acidosis (may exist in asymptomatic patients as well)
- Altered level of consciousness, neurologic deficit.
- Vomiting.

c) Cardiopulmonary arrest, manifesting as:

- Apnea
- Asystole, ventricular tachycardia or fibrillation, bradycardia
- Immersion syndrome

d) Obviously dead, as noted by:

- Normothermic with asystole
- Apnea
- No apparent CNS function
- Rigor mortis
- Dependent lividity
- The following clinical conditions need to be excluded
- Spinal Cord Injuries
- Head trauma
- Cardiac Arrhythmias
- Seizures

Laboratory workup

An electrocardiogram is indicated if there is evidence of significant tachycardia, bradycardia, or dysrhythmia or risk of underlying cardiac disease. Arterial blood gas analysis is probably the most reliable clinical parameter in patients who are asymptomatic or mildly symptomatic. A surprising degree of hypoxia can exist without clinical signs.

Draw blood for serum glucose levels, complete blood cell count, serum electrolyte levels, liver enzymes, lactate level, and coagulation profile, if indicated. Continuous pulse oximetry and cardiorespiratory monitoring may be needed.

Chest radiography should be done for evidence of aspiration, pulmonary edema, or segmental atelectasis suggesting foreign body aspiration.

Acute renal impairment is known to occur frequently in near drowning, and while usually mild, severe renal impairment requiring dialysis may occur. If initial tests show elevated serum creatinine, marked metabolic acidosis, abnormal urinalysis, or significant lymphocytosis, serial estimations of serum creatinine should be performed.

Cervical spine radiograph or computerized tomography (CT) scanning is helpful in individuals with history of trauma, neck pain, or if doubt exists about the circumstances surrounding the submersion injury. Non contrast head CT scanning is helpful in an individual with altered mental status and a suggestive or unclear history of head trauma.

Treatment

Pre Hospital Care

Optimal pre-hospital care is the most significant determinant of outcome in the management of immersion victims. The patient should be removed from water at the earliest opportunity. If spinal trauma is suspected the individual should be moved the least amount possible, with attention to cervical spine stabilization.

The primary aims of treatment of the near drowning cases should be in the order of priority, as below.(7)

- Effective immediate relief of hypoxia.
- Restoration of cardiovascular stability.
- Prevention of heat loss.
- Speedy evacuation to hospital.

As in any rescue initiative, initial treatment should be geared toward ensuring patency of the airway, breathing, and circulation. Initiate rescue breathing immediately, if feasible even while the patient is still in the water. Chest compressions are not effective in the water and waste valuable time. The Heimlich maneuver has not been shown to be effective in removing aspirated water. In the patient with an altered mental status, the airway should be checked for foreign material and vomitus and debris visible in the oropharynx should be removed with a finger-sweep maneuver. Higher pressures may be required for ventilation because of the poor compliance resulting from pulmonary edema. Supplemental 100% oxygen by mask should be administered as soon as available. The degree of hypoxemia may be difficult to determine on clinical observation. Begin rewarming; wet clothing is ideally removed before the victim is wrapped in warming blankets.

Hospital Care (7-9)

Even those victims who appear normal on arrival at hospital can deteriorate rapidly. An accurate and rapid initial assessment of the victim is essentialInitial management of near drowning should place emphasis on basic life support algorithms and on immediate resuscitation and treatment of respiratory failure, with establishment of an adequate airway and cardiopulmonary resuscitation, if necessary. Associated injuries must be considered, as in any other form of accidental injury. Consider potential spinal injuries, especially in diving accidents. The need for hospitalization is determined on clinical evaluation. Provide all victims of a submersion injury with supplemental oxygen during their evaluations. Noninvasive continuous pulse oximetry is valuable. Patients with completely normal findings on examination and trivial history may be discharged after a 6-hour observational period.

Admit any patient with respiratory symptoms, altered oxygenation by pulse oximetry or blood gas analysis, or altered mental status. The most critical role in management is prompt correction of hypoxemia and acidosis.

Immediate use of supplemental oxygen with laryngeal mask or other devices achieving high fractional inspired oxygen should be instituted. Consider intubation and mechanical ventilation in any patient with poor respiratory effort, altered sensorium, severe hypoxemia, severe acidosis, significant respiratory distress, if a patient is unable to maintain a PaO2 of greater than 60-70 mm Hg (> 80 mm Hg in children) on 100% oxygen by face mask or PaCO2 is > 45 mm Hg. Endotracheal intubation and mechanical ventilation may be indicated in awake individuals unable to maintain adequate oxygenation on oxygen, by mask or via continuous positive airway pressure (CPAP) or in whom airway protection is warranted.

Intubated victims of submersion injury may require 5-10cm H2O PEEP may improve oxygenationpositive end expiratory pressure (PEEP) with mechanical ventilation to maintain adequate oxygenation. PEEP has been shown to improve ventilation patterns in the noncompliant lung in several ways, including 1) shifting interstitial pulmonary water into the capillaries, 2) increasing lung volume via prevention of expiratory airway collapse, 3] providing better alveolar ventilation and decreasing capillary blood flow, and 4) increasing the diameter of both small and large airways to improve distribution of ventilation.

Pulmonary insufficiency due to drowning may warrant use of surfactant, though its efficacy to be used routinely in all cases has not been demonstrated.

Bronchoscopy may be necessary for removal of significant inhaled foreign bodies, such as water debris or aspirated food

Intravascular volume depletion is common, secondary to pulmonary edema and intracompartmental fluid shifts, regardless of the type of fluid aspirated. Rapid volume expansion may be indicated using isotonic saline. Ventricular dysrhythmias (typically, ventricular tachycardia or ventricular fibrillation), bradycardia, and asystole may occur as a result of acidosis and hypoxemia, rather than due to electrolyte imbalances. Inotropic support may be required using dopamine or dobutamine. Central venous pressure monitoring may be warranted.

Most acidosis is restored after correction of volume depletion and oxygenation. Sodium bicarbonate may be administered in cases of severe acidosis that do not correct using the above measures, but only administer it after adequate ventilation has been established.

Most immersion victims become hypothermic gradually and are at risk for ventricular fibrillation and neurologic injury. Re-warming method is dependent on the degree of hypothermia and the patient's response. Aggressively rewarm hypothermic patients to restore normal body temperature. Core rewarming with warmed oxygen, continuous bladder lavage with fluid at 40°C, and intravenous infusion of isotonic fluids at 40°C should be initiated during resuscitation. Warm peritoneal lavage may be required for core rewarming in severely hypothermic patients.

Place a nasogastric tube for removal of swallowed water and debris and to assist in rewarming efforts. Urinary catheterization for ongoing urine output measurement may be warranted to assess urine output. The benefits of resuscitative efforts should be continuously reassessed in such situations.

Initiate appropriate treatment of hypoglycemia and other electrolyte imbalances, seizures, bronchospasm, cold-induced bronchorrhea, dysrhythmias and hypotension as necessary.

Corticosteroids have been shown to be of no benefit in the management of near drowning. Routine antibiotic prophylaxis is not indicated unless the patient was submerged in grossly contaminated water or sewage.

Patient disposal depends on the history, presence of associated injuries, and degree of immersion injury. Victims, who only have mild symptoms that improve during observation and have no abnormalities on arterial blood gas studies or pulse oximetry and chest radiograph, should be observed for a more prolonged period of time in the emergency department (about 6 hours). Certain patients may display mild to moderately severe hypoxemia that is corrected easily with oxygen. Admit these patients to the hospital for observation and discharge only after resolution of hypoxemia, if they have no further complications. All patients requiring intubation and mechanical ventilation should be admitted to the Intensive Care Unit. Varying degrees of neurologic as well as pulmonary insults typically complicate their courses.

COMPLICATIONS

Immediate complications are secondary to hypoxia and acidosis. The immediate threat is the effect on the cardiovascular system. Hypoxia and acidosis may lead to cardiac dysrhythmias, including ventricular fibrillation and asystole. Myocardial damage may lead to cardiogenic shock. Monitor and maintain intravascular volume and blood pressure. Central venous pressure (CVP) monitoring is useful in those patients requiring intensive care.

Aspiration of fresh or salt water alters the function of surfactant, causing injury to the alveoli and pulmonary capillaries. Increased capillary permeability can worsen the hypoxia. Continuous pulse oximetry is useful. The early use of supplemental oxygen with high levels of positive end-expiratory pressure is helpful in reversing hypoxemia.

Central nervous system effects depend on the severity and duration of hypoxia. Post hypoxic cerebral hypo perfusion may occur. Cerebral edema and intracranial hypertension secondary to hypoxic neuronal injury is frequently observed, but studies have shown that invasive monitoring of intracranial pressure is neither useful nor necessary in near-drowning incidents.

Near-drowning patients frequently develop pneumonia, often due to secondary bacterial infections. Whether prophylactic antibiotics are beneficial is still controversial. Chemical pneumonitis also is not infrequent, especially if the submersion occurs in chlorinated or severely contaminated pools.

PROGNOSIS

The most significant impact on morbidity and mortality occurs before the patient arrives at the hospital. The prognosis is related directly to the duration and magnitude of hypoxia. Poor survival is associated with the need for continued cardiopulmonary resuscitation efforts on arrival to the hospital. Many survivors have long-term neurologic sequelae. If they recover from the pulmonary effects of the submersion, patients who are fully awake on arrival to the hospital generally do very well. Neuro-protective effects only seem to occur if the hypothermia occurs at the time of submersion and only with very rapid cooling in water less than 5°C.

PREVENTION

In most instances, drowning and near drowning can be prevented with simple safety measures and common sense. Most young children enter a swimming pool directly adjacent to their home or one with inadequate fencing or unlatched gates or doors.

Adult supervision is essential in the prevention of drowning. Because lapses of supervision are inevitable, other safety precautions must be in place. The use of adequate fencing around swimming pools decreases the number of immersion injuries significantly. The enclosure may be a wall or fence at least 4 feet tall that completely surrounds a pool on all four sides. Doors and gates to the pool should be self-closing and self-latching.

The use of personal flotation devices may reduce the incidence of drowning among children when playing in natural bodies of water or when boating.

Pool owners should be trained on basic life support.

Both children and adults should be instructed to never swim alone or unsupervised.

Alcohol and drugs should not be used when operating or riding in motorized watercraft.