

Children younger than 1 year old are most likely to have a submersion injury in a bathtub, whereas top-heavy toddlers fall head first into a pail of liquid and are unable to free themselves (Caglar and Quan, 2016). Preschoolers are at risk for injury in swimming pools, and school-age children and adolescents are most commonly at risk in natural bodies of water, such as lakes, ponds, and rivers (Caglar and Quan, 2016). The suction created at the outlet of pools, hot tubs, or whirlpool spas is strong enough to trap any child, even larger children, underwater. Submersion injury as a form of fatal child abuse has also been recognized as a problem.

## Pathophysiology

Physiologically most organ systems are affected, especially pulmonary, cardiovascular, and neurologic systems. Cerebral hypoxia is a major component of morbidity and mortality with submersion events. Within minutes of a submersion, a lack of oxygen leads to loss of consciousness and progressive decreased cardiac output and ultimately apnea and cardiac arrest (Caglar and Quan, 2016). Recovery depends on the timeliness and effectiveness of initial resuscitation and subsequent supportive care measures.

Physiological features in submersion injuries are hypoxia, aspiration, and hypothermia.

**Hypoxia** is the primary problem because it results in global cell damage with different cells tolerating variable lengths of anoxia. Neurons, especially cerebral cells, sustain irreversible damage after 4 to 6 minutes of submersion; but the heart and lungs can survive up to 30 minutes. Regardless of the amount of liquid aspirated, if the victim suffers arterial hypoxemia (resulting from atelectasis and shunting of blood through the nonventilated alveoli), combined respiratory acidosis (resulting from retained carbon dioxide), and metabolic acidosis (caused by buildup of acid metabolites from anaerobic metabolism). Approximately 10% of submersion injury victims die without aspirating fluid but succumb from acute asphyxia as a result of prolonged reflex laryngospasm.

**Aspiration** of fluid occurs in the majority of submersion injuries. The aspirated fluid results in pulmonary edema, atelectasis, airway spasm, and pneumonitis, which aggravates the hypoxia.

**Hypothermia** is common after submersion, and children are at an increased risk of hypothermia because of their large surface area