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Authors:

Kurt Weber, MD, Associate Professor, Department of Emergency Medicine; Assistant Director, Department of Research Operations, Orlando Regional Medical Center, Orlando, FL.

Clifford Denney, MD, Department of Emergency Medicine, Orlando Regional Medical Center, Orlando, FL.

Philip Giordano, MD, Associate Professor and Vice Chairman, Department of Emergency Medicine, Orlando Regional Medical Center, Orlando, FL.

Peer Reviewer:

Andrew D. Perron, MD, FACEP, FACSM, Professor and Residency Program Director, Department of Emergency Medicine, Maine Medical Center, Portland, ME.

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Management of the Drowned Patient

"Critical alert. Be advised we are en route with a 23-month-old child found submerged in a swimming pool. Unknown down time. Patient obtunded, assisting respirations. ETA 3 minutes." This is a typical prehospital call for a drowned patient, and it results in the entire staff gearing up for the incoming patient. Respiratory therapists check and double-check their intubation equipment. The nurses prime their heated IV pumps and assemble warmed blankets anticipating a hypothermic patient. The radiology team waits at the bedside with a portable X-ray machine. Social workers are alerted and wonder aloud how parents could allow a 23-month-old child to become submerged in a pool.

The emergency physician (EP) is, of course, thinking about all these things and more. During the initial stabilization, the EP must consider the precipitating events. Was there a seizure before the event? Could there have been trauma leading to the drowning? What is the chance of a cervical spine injury? The EP must then anticipate the next steps in care. The patient above will be intubated and admitted to the intensive care unit (ICU); this decision is easy. However, a drowned patient who arrives asymptomatic or displaying only mild symptoms makes a more difficult disposition. The EP must consider the ultimate prognosis and be able to relay this information to concerned parents.

The drowned patient represents a unique and difficult challenge. A wide range of physiologic insults may occur, making each management decision critical. This review describes the epidemiology, pathophysiology, critical actions, and prognostic factors the emergency physician must know to provide the best care for the drowned patient.

—Sandra M. Schneider, MD, Editor

Definitions

The spectrum of submersion injuries ranges from death in the field to minor sequelae from the event. Accordingly, multiple terms have been used, leading to some confusion. In the past, drowning usually implied death from an initial submersion event. The often-used term near-drowning implied multiple situations ranging from definite survival to survival of the initial submersion event regardless of ultimate outcome.[1] Some definitions have incorporated pathophysiology, i.e., wet vs. dry drowning while others used outcomes, i.e. hospitalization vs. no hospitalization.[1,2] In all, a review of the literature between 1960 and 2002 found 20 definitions for drowning and 13 for near-drowning.[2]

Realizing the need for standardization, a multidisciplinary consensus group announced a formal definition at the 2002 World Congress of Drowning. Their recommendation reads: "Drowning is a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium."[1] The group discouraged the use of misleading historical terms such as active/passive, wet/dry, primary/secondary, and near drowning. This definition serves as the basis for guidelines for uniform reporting of data in drowning victims[1] and has gained the support of both the World Health Organization and the Centers for Disease Control and Prevention (CDC).[3,4] A standard approach should promote cohesive research; however, many historical terms persist in the literature. These inconsis-

Executive Summary

- Previous literature differentiated between wet and dry drowning. Clinically, "dry drowning" is rare and is not different from "wet." In addition, there is no difference between salt- and fresh-water drowning. RBC lysis and electrolyte shifts are not common.
- Drowning is most common in the pediatric age group, particularly the very young. Fencing around swimming pools is the best preventive measure.
- Patients who are asymptomatic after a submersion incident can be watched in the ED for 4-6 hours. If they remain asymptomatic, they can be discharged home.
- Resuscitation follows ACLS guidelines. Cervical spine injuries occur but are rare.

tencies are a result of the complex pathophysiology of the drowning process and the wide range of clinical presentations in the drowned patient.

Epidemiology and Risk Factors

Drowning contributes significantly to accidental deaths. In 2005, the CDC reported that 3,582 unintentional drowning deaths occurred in the United States (more than 10 per day).[5,6] This ranked second overall in mortality due to unintentional injury in those younger than 45 years old. More than triple this number visited emergency departments for submersion events, with 1-4 hospitalizations occurring for every drowning death.[5,6] Population data showed states such as Florida, California, and Arizona, where swimming pools and natural bodies of water are most prevalent, saw the highest number of drowning incidents.[7]

Younger ages are significantly associated with downing. Overall, drowning is proportionally the highest-ranking cause of accidental death in those younger than 24 years of age.[7] In fact, drowning caused nearly 30% of deaths in those between 1 and 4 years old in 2005.[6] Furthermore, in 2006, as shown in Figure 1, this age group accounted for nearly half of all pediatric drownings. Not surprisingly, seasonal variance exists as well. The National Safe Kids Campaign found that two-thirds of drownings in children 14 years old or younger occurred between May and August.[8] Males account for approximately 75% of drowning deaths in those older than 12 months, as they tend to engage in riskier swimming behavior.[6,9] Finally, the CDC reports that African American children have a rate of drowning approximately 3.2 times higher than Caucasians between the ages of 5 and 14.[6]

Location of drowning in pediatric patients varies with age. About half of drownings among infants younger than 1 year occur in the bathtub. Approximately 50% of drowning deaths in children from 1 to 4 years of age occur in swimming pools. In older children and young adults, natural bodies of water provide the setting of drowning about 65% of the time.[9]

Experts often cite alcohol abuse as a major contributor to submersion injuries. Studies estimate that those who ingest alcohol while engaging in activities where drowning can occur increase their risk of death due to submersion by about 5 to 30 times, depending on their blood-alcohol level.[10] Half of those involved in drowning related to boating accidents consume alcohol.[11] Enforcing more stringent alcohol laws may decrease deaths by drowning by up to 80%.[10]

Swimming ability may not provide protection against drowning. Population-based studies have demonstrated conflicting results. Depending on the study, 20-70% of drowning victims possess the ability to swim. Mortality data reported by the Canadian government in 1998 reported that only 31% of drowning patients either lacked the ability to swim or were considered weak swimmers.[12] This makes logical sense when one considers that stronger swimmers more often expose themselves to more dangerous situations in the water, such as swimming far from land or performing difficult maneuvers while in the pool.[12]

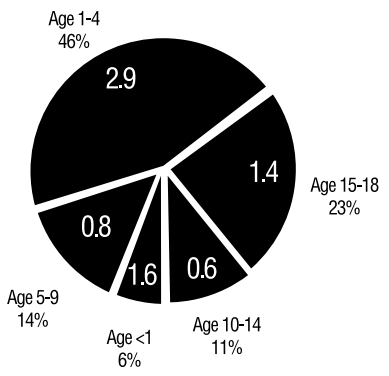
Existing neurologic conditions also increase risk of submersion injuries. Studies investigating epilepsy show that this disease increases risk of drowning by 15-19 times.[13] A significant number of these drowning deaths occurred during bathing. For this reason, many experts on epilepsy recommend showering over bathing in patients with seizures disorders.[13] Research also suggests that psychiatric disorders and developmental delay in conditions such as autism also are linked with a higher incidence of submersion injuries.[14]

Finally, cardiac abnormalities heighten the risk of drowning. Population-based studies report approximately 20% of drowning victims over a 15-year period had a history of cardiovascular disease.[15] Case reports link long QT syndrome with drowning risk.[16,17] Educating patients who have a history of these medical problems is essential, as it may decrease the risk of drowning for these individuals.

Pathophysiology

During normal submersion (i.e., swimming), the body undergoes primitive life-sustaining physiologic alterations, the "diving reflex," illustrated in the top half of Figure 2. Bradycardia develops, decreasing the oxygen demand of the heart. Cardiac output is maintained through peripheral vasoconstriction. This vasoconstriction shunts blood to vital organs and away from the periphery of the

Figure 1: Pediatric Deaths from Drowning (n = 1052)



Rate per 100,000 in white
Data source: CDC/NCIPC Vital Statistics

body in an attempt to conserve body temperature.[18] Furthermore, research measuring cerebral blood flow during an evoked dive reflex shows that cerebral blood flow increases.[19] Although measurable changes occur during harmless submersion, the implications of these physiological changes remain largely unknown in drowning.

The physiology of drowning differs from routine water submersion. The sequence of events, shown in the bottom half of Figure 2, begins when the victim remains submersed in a liquid medium long enough to hinder normal respiration.[1] Panic then ensues while the victim struggles to keep his or her head above water. Unsuccessful attempts at this eventually lead to breath-holding. A period of laryngospasm then occurs, which results in a cessation of gas exchange. Eventually, laryngospasm ends, and the patient aspirates a large volume of fluid.[1,20,21] As seen in Table 1, a complex physiologic cascade adversely affecting multiple organ systems then ensues.

Earlier work regarding drowning attempted to divide the physiological events that followed submersion into two categories: wet-drowning and dry-drowning. The above-mentioned process of aspiration that leads to lung injury and hypoxemia describes wet-drowning. In contrast, some described dry-drowning as a process in which the cessation of laryngospasm fails to occur, leading to asphyxiation in the absence of significant liquid aspiration.[2] Earlier researchers believed that this latter sequence of events made up 10-15 percent of drowning events.[22] More recently, however, experts doubt that this mechanism plays a significant role in submersion injuries.[22,23] Studies that evaluate lungs on autopsy after drowning show an absence of significant water aspiration less than 4% of the time.[22] In addition, damage occurs to the lungs when the victim aspirates as little as 1-3 mL/kg of fluid.[20]

Since only a small volume of fluid results in injury, deleterious pulmonary changes occur early in the process. Capillary permeability greatly increases, leading to pulmonary edema. Aspirated water damages and washes away surfactants, leading to a progression of atelectasis and ventilation/perfusion mismatches. The victim remains hypoxic even after removal from the water when significant lung injury has occurred.[20,21]

Adverse hemodynamic effects occur as a result of the hypoxemia to the myocardium. Cardiac output drops, contributing to poor perfusion of end-organs. Pulmonary hypertension occurs as a consequence of the lung injury.[20] Case reports describe conduction abnormalities as well, described in the past by the term immersion syndrome.[24] Contact with water colder than body temperature may precipitate cardiac dysrhythmias. Catastrophic cardiac rhythm disturbances such as ventricular tachycardia and asystole due to prolongation of the Q-T interval have been described.[16,17] As illustrated in Figure 3, patients with known QT abnormalities are at particular risk because the normal physiologic changes occurring during submersion can unmask and potentiate the underlying cardiac anomalies.[16,25]

Submersion can result in neurological sequelae ranging from brief loss of consciousness to devastating coma and brain death. Multiple biochemical processes in the brain occur secondary to anoxic injury, which eventually lead to neuronal death. These hypoxic changes may be seen early on by MRI.[26] Drowning in icy water may offer some protection from this process, lessening the degree of neurologic injury. Experts believe that colder water decreases the cerebral oxygen demand of the brain as the body temperature drops.[21,27,28] In addition, colder body temperature may protect against free radical formation from reperfusion.[29] These factors appear to lessen the deleterious effects of drowning on brain injury.

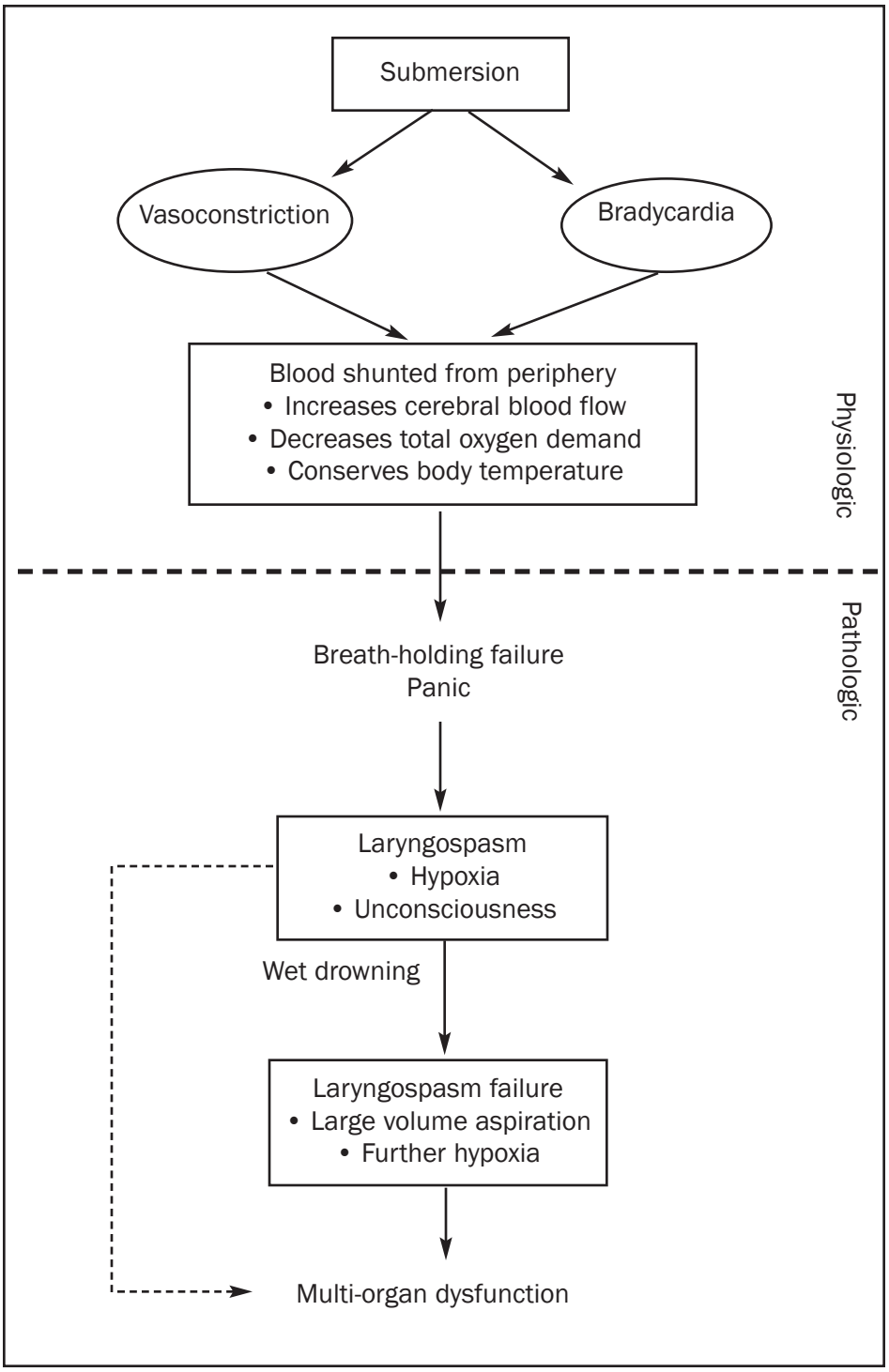
In the past, it was thought that metabolic changes other than those caused by hypoxemia alone occurred in submersion injury. Research in animals in the 1930s showed that salt water submersion resulted in significant increases in certain serum electrolytes, while fresh water submersion caused dilutional effects. In addition, it was believed that fluid shifts led to red blood cell (RBC) lysis, causing anemia and hyperkalemia.[30] Later research in humans, however, showed these metabolic derangements fail to play a clinically significant role. One study that evaluated submersion victims over a 17-year period showed that electrolyte and hemoglobin abnormalities were rare.[30] The fact that the average human aspirates approximately 2-4 mL/kg during submersion injury as opposed to 10 mL/kg used in the early animal models may explain this finding. Only a small number of patients show significant anemia when presenting after a submersion event, and many of these probably suffered from an underlying anemia prior to underwater injury.[30]

Clinical Presentation and Differential Diagnosis Considerations

There is a large spectrum of patient presentations after drowning. Some of the signs and symptoms result from the event itself; however, strong consideration of precipitating causes is essential when evaluating these patients. Obtaining a succinct but thorough initial history plays an important role in patient management.

Questions addressing the location of the event, temperature of the

Figure 2: Drowning Process



water, and submersion time prove important when considering management. Witnesses can provide details surrounding the event, such as a seizure or trauma preceding submersion. Loss of consciousness or bystander CPR may lead the emergency physician to suspect a more serious submersion injury. The localization of pain or external signs of trauma provide clues of concomitant injuries. Past medical history, including medications, may indicate the precipitating cause of the submersion or provide an idea of possible complications to anticipate regarding that patient in particular. (An example would be an acute myocardial infarction precipitated by the stress of drowning.)

Drowning victims mandate early evaluation. Airway patency and breathing pattern are always a top priority in any critical emergency department patient. Assessing vital signs early is essential. Monitoring should be started early to detect a cardiac dysrhythmia that requires immediate attention. Body temperature allows estimation of duration of submersion and water temperature. Finally, respiration rate and oxygen saturations serve as early clues to the severity of lung injury.

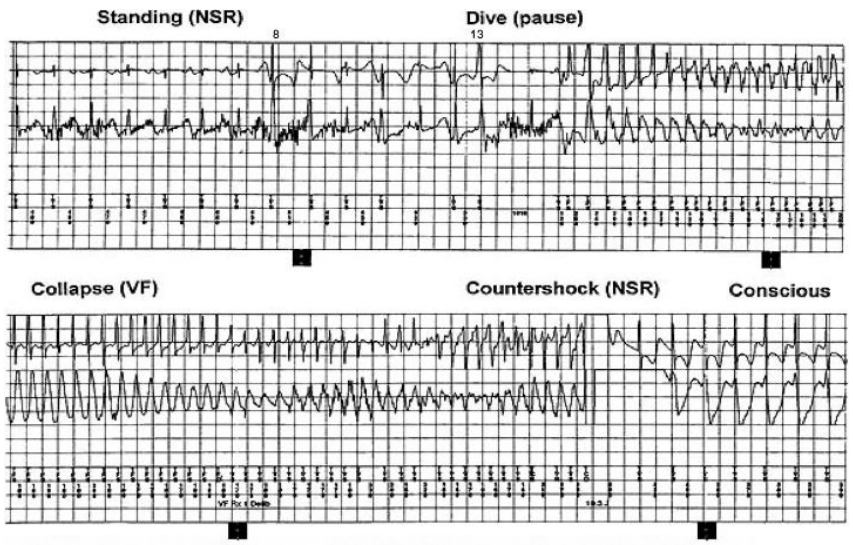
A full head-to-toe physical examination is crucial when assessing these patients. Scalp lacerations, hematomas, or contusions signal head trauma. Pupillary size and response may indicate brain herniation if fixed and dilated or suggest substance ingestion such as narcotics if pinpoint. Consideration must be given to cervical spine injuries, especially in suspected trauma. A careful cervical-spine examination provides useful information if the person remains fully awake and alert without distracting injury, but cannot be relied upon in other cases.[31] A population-based study performed over a 22-year period showed less than 1% of all patients involved in a submersion event suffered an injury to the cervical spine.[32] Nevertheless, proper cervical spine precautions should be maintained until the physician can reliably rule out that an injury is present.

An abnormal pulmonary examination provides evidence of lung injury. The detection of subtle wheezing, rales, or rhonchi suggests a mild degree of insult. On the other hand, severe respiratory distress including tachypnea, hypoxia, and accessory muscle use during breathing suggests extensive pulmonary injury. Cyanosis is an ominous finding that usually requires endotracheal intubation. In situations of mild symptoms, the dynamic state of the respiratory status requires close observation for any worsening. A study involving adult patients who presented to the emergency department after suffering a submersion event showed 95% of these patients exhibited some degree of hypoxemia, while roughly 40% developed adult respiratory distress syndrome (ARDS).[33]

Table 1: Multi-System Dysfunction

System	Impairment
Pulmonary	Edema, V/Q mismatch, hypoxemia, ARDS
Neurologic	Anoxic encephalopathy, traumatic brain/cord lesions
Acid/base	Metabolic acidosis
Cardiac	Decreased cardiac output, dysrhythmia, infarction
Renal	Azotemia

Figure 3: Dysrhythmia from Submersion



Seen starting at the 8th beat, underwater submersion results in bradycardia ("diving reflex"). This bradycardia accentuates the QT interval and allows generation of PVCs. At the 13th beat, during a deep dive, a PVC results in a long compensatory pause. The next beat, a sinus complex, is followed quickly by a PVC that degenerates into a polymorphic ventricular tachycardia, torsades des pointes. The patient is then defibrillated successfully (bottom strip).
Figure used with permission from: Batra AS, Silka MJ. Mechanism of sudden cardiac arrest while swimming in a child with the prolonged QT syndrome. *J Pediatrics* 2002;141: .

Several causes of dysrhythmias exist during a submersion event. Preexisting conduction abnormalities predispose patients to drowning.[16,17] Also, hypoxemia experienced as a result of submersion may precipitate a cardiac dysrhythmia. Hypothermia causes cardiac conduction abnormalities and worsens as body temperature decreases.[34]

The physician should consider other possible precipitants of drowning, including substance abuse, seizures, hypoglycemia, syncope, and acute cerebrovascular accident. A thorough physical examination assesses the likelihood of trauma related to the event. In children, physical examination findings such as bruising at different stages, spiral fractures, and retinal hemorrhages suggest child abuse, which occurs infrequently. In one study, about 13% of all child homicides were due to drowning.[35]

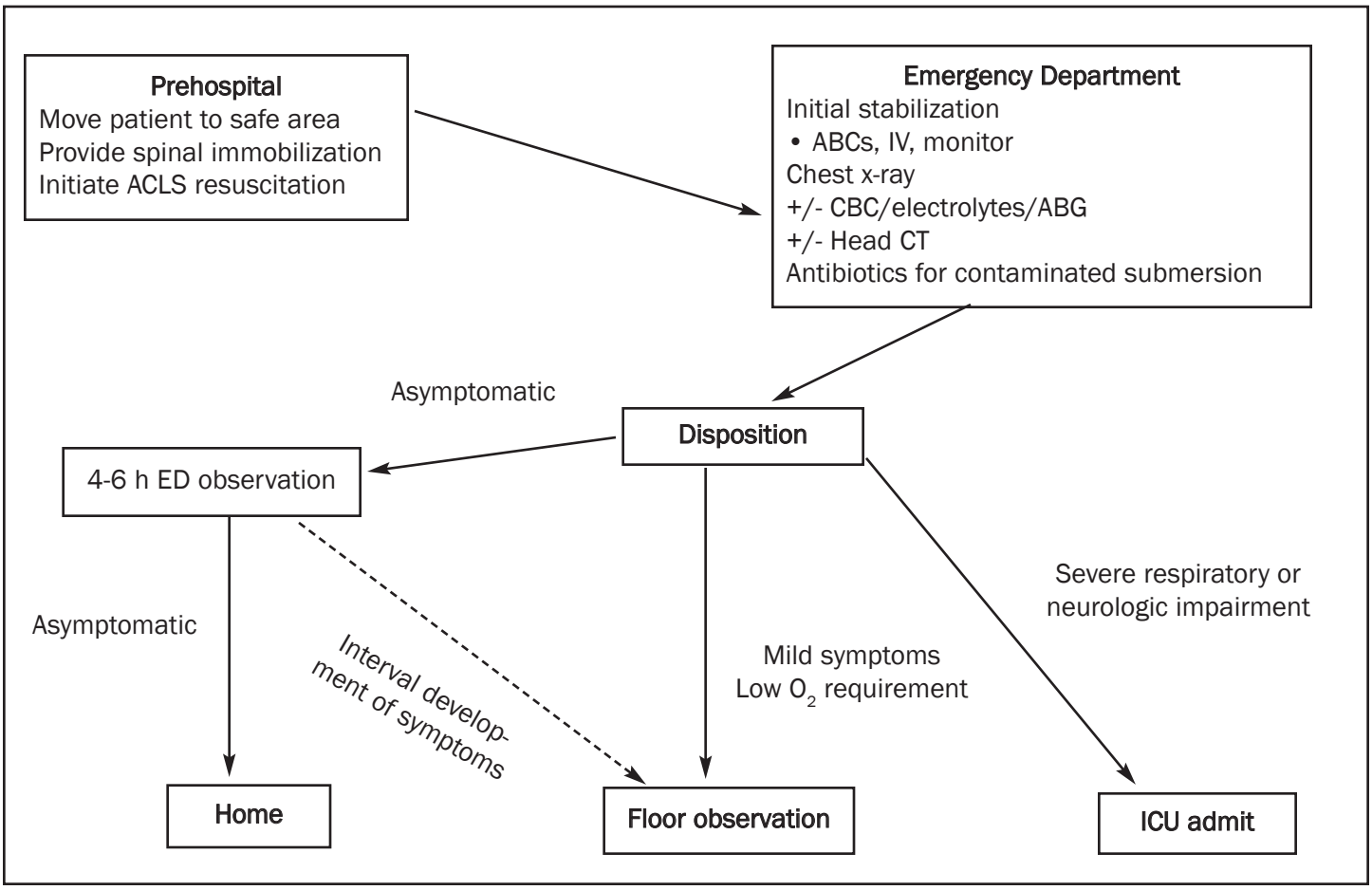
Management

Ideally, aggressive management of the drowning patient begins at the scene and follows through to the emergency department, as demonstrated in Figure 4. The victim should be removed from the water as quickly as possible. The American Heart Association (AHA) supports early initiation of rescue breathing in apneic patients in its 2005 recommendations on Advanced Cardiac Life Support (ACLS). This may be initiated in shallow water as long as the rescuer can safely do so. In cases in which the victim remains in the water and the rescuer cannot easily open the airway, the committee recommends mouth-to-nose ventilation.[36] The Heimlich maneuver to remove water or aspirated material from the airway does not have a role in prehospital care of the drowning patients.[37] Aspirated particulate matter provides no airway obstruction requiring dislodgment. In addition, repeating the Heimlich maneuver in the drowning patient delays hospital arrival and poses a risk to anyone with a cervical spine injury.[37]

Patients experiencing cardiac arrest after drowning should be treated similarly to cardiac arrest in other situations, i.e., early CPR, minimizing interruptions in chest compressions, and early defibrillation. Concern exists regarding the safety of defibrillation in a wet environment. Currently, the AHA does not recommend any modification of ACLS in the drowning patient.[36] Experiments show that although the rescuer may notice minor sensation when performing defibrillation in a pool of salt water, defibrillation may be performed safely in wet environments.[38] If rescuers take care to dry and step away from the patient, no significant electric current reaches them.

Upon arrival to the emergency

Figure 4: Drowning Management



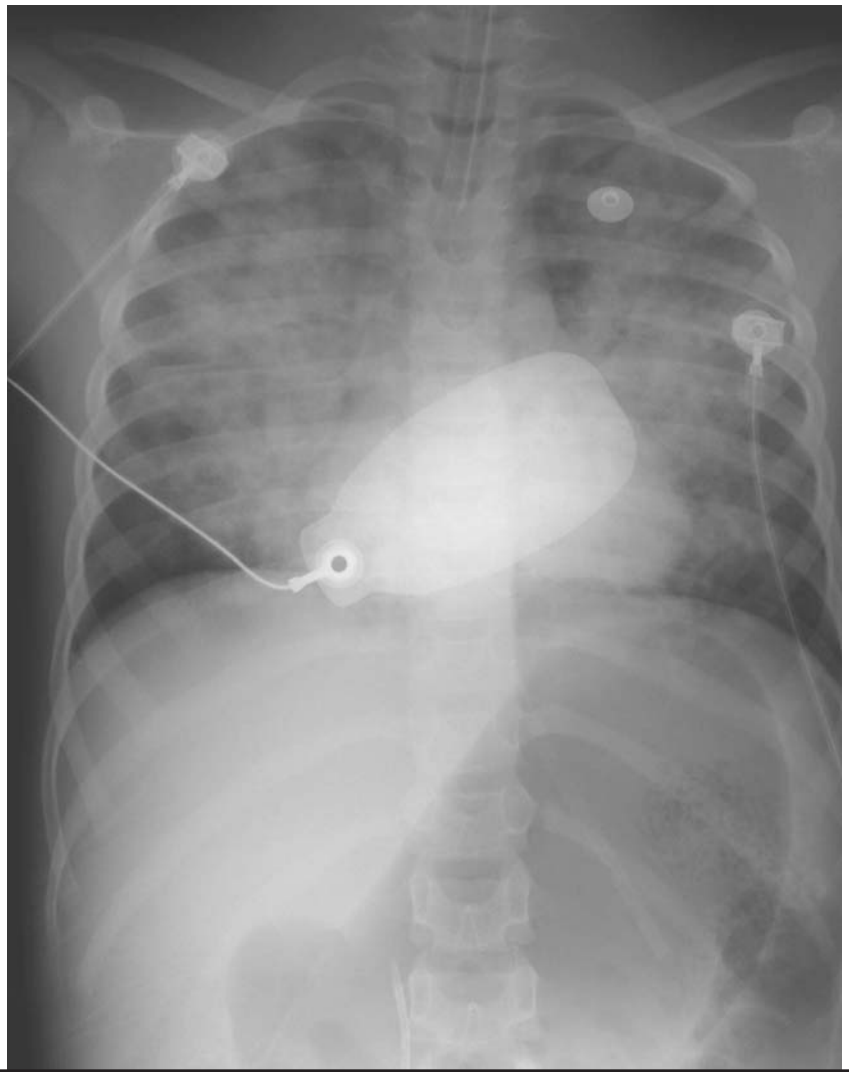
department, patients should be placed on a cardiac monitor with a continuous pulse oximeter. A serum glucose reading, often done in the prehospital setting, evaluates for hypoglycemia that could have precipitated or resulted from the preceding events. A primary survey, assessing airway patency, breathing adequacy, circulatory status, and cervical spine protection, offers a starting point for patient assessment. If not already present, two large-bore peripheral IVs should be placed by nursing staff.

Early airway management plays a crucial role in caring for these patients. The degree of pulmonary injury resulting in hypoxemia varies. As mentioned above, a spectrum of pulmonary injury frequently is seen after drowning. A study in adults performed over an eight-year period showed that although fewer than 10% of patients who presented after a submersion event required intubation, about 80% showed some degree of pulmonary edema on chest X-ray.[33] Pediatric patients presenting to emergency departments often present more critically ill than adults, requiring intubation about half of the time.[39] Although no definitive criteria for intubation universally apply, factors such as hypoxemia after supplemental oxygen, poor ventilation manifested by increased $PaCO_2$ levels, and decreased level of consciousness resulting in failure to protect the airway indicate that intubation and mechanical ventilation may be necessary.

ACLS or Pediatric Advanced Life Support (PALS) protocols should be followed for hemodynamically unstable patients. Gentle fluid resuscitation may aid in supporting blood pressure, but consider that overzealous fluid administration could worsen pulmonary edema. An ECG screens for any conduction abnormalities, such as QT prolongation.[16,17,25] Also, drowning may precipitate acute myocardial infarction, which also may be detected by ECG.[40]

Further diagnostic testing may aid in management. The majority of patients will exhibit abnormal chest roentograms, as shown in Figure 5. The EP must keep in mind that early imaging may underestimate the extent of damage, which may develop over a few hours.[41] Patients who present after a moderate to severe drowning episode should have laboratory tests performed. An arterial blood gas also can help provide accurate values on oxygenation, ventilation, and pH. Although large fluid and electrolyte shifts do not typically occur as a result of drowning,[30,42,43] routine testing of serum electrolytes and renal function should be obtained in patients who experience prolonged submersion. One study showed that about 50% of patients admitted to the hospital suffered from some degree of acute renal failure, and a few from rhabdomyolysis.[44,45] While most of these patients' renal function recovered, 7% required hemodialysis.[44,45] A coagulation evaluation is important in patients taking drugs such as warfarin or heparin or if

Figure 5: Pulmonary Infiltrates after Submersion



the physician suspects disseminated intravascular coagulation.

Emergency physicians should consider the possibility of concomitant traumatic injuries. A large study in drowning patients showed that only patients with a mechanism of significant trauma or an abnormal physical examination showed evidence of cervical spine injury.[32] The American Heart Associations' 2005 guidelines on ACLS recommend placing a cervical collar only on patients who fit this description.[36] Head CT should be obtained in patients who have suffered significant head trauma or show focal neurological deficits on physical examination. Extremity radiographs help evaluate those with abnormal musculoskeletal examinations.

Therapeutic hypothermia improves neurological outcomes in comatose patients following a ventricular fibrillation arrest.[29] Inducing and/or maintaining hypothermia for comatose drowning patients may offer improved outcomes in drowning patients as well. Multiple case reports exist showing that adult drowning patients who present in coma may benefit from therapeutic hypothermia, even after prolonged periods of submersion.[46,47] Further evidence must be obtained, however, before this becomes the standard of care.

Pneumonia, although a rare complication of drowning, causes significant morbidity. Submersion in contaminated water such as sewage water increases risk.[48] Case reports describe pneumonia from multiple bacterial pathogens including Aeromonas, Klebsiella, and Legionella species, and fungal causes such as aspergillus, rhizopus, and zygomycosis.[48-51] In fact, 60% of those who develop pneumonia after a submersion episode will die.[48] Specifically, reports show that Aeromonas pneumonia often develops within 24 hours of submersion and results in high mortality.[48,49] Even in light of the such severe clinical consequences, prophylactic antibiotics rarely play a role in management of drowning patients.[48] Studies fail to support improved outcomes with the administration of prophylactic antibiotics.[52,53] Drowning in contaminated water, fever, or pulmonary deterioration a few days after the initial event prompt the consideration for antibiotics. Antibiotic choice includes extended-spectrum penicillin plus a ß-lactamase inhibitor and gentamicin or clindamycin and a fluoroquinolone.[48]

Prognosis

Clinical outcomes in drowning cases range from quick return to physiologic baseline to severe neurologic deficits. A large body of research exists attempting to identify variables that predict the clinical course and severity following a submersion event. (*See Table 2.*) Factors such as age of the patient, submersion time, temperature of water, and patient presentation all influence outcome.

In the past, many experts in submersion injury hypothesized that pediatric patients had a favorable prognosis when compared to adults.[54] Pediatric patients experience more rapid cooling due to their small body-surface-areas.[55] In addition, adults more often suffer from other comorbidities that may contribute to a worse outcome. More recent studies suggest that there may not be a survival advantage in younger patients. A study over a 12-year period comparing survival and neurologic outcome in patients admitted to the intensive care unit showed no difference in outcomes in pediatric patients vs. adults.[54]

Longer submersion time correlates with a worse prognosis. Studies involving pediatric patients estimate submersion times longer than 5-10 minutes correlate with worse outcomes.[56,57] Studies involving adults echo this

finding. Patients who survived with full neurologic recovery remained submersed for an average of 5 minutes, while those who suffered some neurological insult and those who died had median submersion times of 10 and 16 minutes, respectively.[54] Submersion time does not provide infallible prognostic value since it often is incorrectly estimated by bystanders.[54] In addition, case reports exist describing survival after submersion times greater than 1 hour.[58] For these reasons, the emergency physician should initiate aggressive resuscitation early.

Hypothermia due to colder water temperatures may improve clinical course in drowning. This typically occurs after submersion in icy water; however, case reports exist reporting this effect even in locations such as Florida.[58] Hypothermia decreases cerebral metabolism and oxygen demands.[59] A study performed over a 10-year period of approximately 300 children showed that those submersed in water temperatures less than 15 degrees Celsius experienced a reduction in poor outcome defined as death or severe neurological sequelae by greater than 30 times compared to those submersed in warmer water.[60] Studies in adult patients yield mixed results that make it difficult to definitely conclude that submersion in cold water provides an advantage in them.[54,56]

A few reasons may explain this discrepancy in findings. First, not only does cerebral metabolism slow with hypothermia, but cerebral perfusion decreases as well. Hypothermia affects cardiac output, resulting in decreased blood flow to the brain.[59] In addition, much of the literature reviewed reports outcomes based on hypothermia rather than measurements of the temperature of the bodies of water. In this setting, two causes of hypothermia exist. The decreased body temperature may result from potentially protective hypothermia due to cold water submersion, or hypothermia as a result of the patient decompensation. The latter would be expected to be associated with poor outcomes.

Prehospital care plays an important role in prognosis for submersion victims. Bystander initiation of basic life supports is the first important step in minimizing brain damage. An eight-year study involving pediatric patients showed a much better outcome when bystanders initiated resuscitation versus those in which bystanders waited for paramedics to initiate resuscitation. The best outcomes occurred in those who received mouth-to-mouth breathing plus chest compression, while an improvement in clinical course also was observed in those receiving only chest compressions.[61]

Rapid arrival by emergency medical services is a factor in survival. Approximately 10% of drowning victims who suffer from pulseless arrest show a shockable rhythm, and evidence supports worse outcome with longer ambulance response times.[62] Comparisons between prehospital cardiac arrest due to drowning versus cardiac disease showed an improvement in survival in the drowning group. One possible explanation is that these patients tended to be younger with fewer comorbidities.[62] Finally, patient survival was found to be extremely low in those who did not respond to advanced cardiac life support for greater than 25 minutes.[63]

Clinical presentation provides an idea of expected clinical course. Patients requiring CPR face a worse outcome.[56] Patients who arrive without any neurological impairment almost always remain as such. In addition, the vast majority of patients who present obtunded but arousable survive without any neurological sequelae.[41,56,64] Initial blood sugar above 400 proves to be a poor prognostic factor in children.[64] Finally, complicated clinical criteria, such as the Pediatric Risk of Mortality Score (PRISM), take into account factors such as vital signs, GCS, electrolyte readings, and coagulation profile that offer preliminary prognostic information. However, drawbacks of this scoring system include the complexity of calculating the score and findings that the intermediate scores fail to provide reliable prognostic information.[65,66]

Table 2: Factors Associated with Favorable Prognosis after Drowning

Demographic
• Younger age
• Female sex
Prehospital
• Shorter submersion time
• Bystander initiated CPR
• Cold water temperature
Emergency Department
• Reactive pupils
• GCS > 13
• Low PRISM score

Emergency Department Disposition

Unfortunately, there are no well-established guidelines to assist the emergency physician with disposition. Patients presenting after submersion injury typically will fall into three groups. The first group has severely compromised respiratory or neurologic function that necessitates aggressive management in the ICU setting. The second group has mild lethargy or thoracic symptoms of pain or dyspnea. In these patients, an overnight stay in an observation unit is warranted. The final group, those patients who are asymptomatic, presents a greater challenge to the practicing EP. Reports in the past cited episodes in which the respiratory status of patients deteriorated clinically after initially appearing to have no pulmonary injury, termed secondary drowning.[67-69] The possibility of deterioration has led some EPs to admit all drowning victims regardless of severity. However, a recent adult study, in which age greater than 60 years old made up 79% of the patients in the study, showed pulmonary improvement as opposed of worsening, after ED presentation.[33] Similarly, a study of 61 pediatric patients showed all of the children who present with an initially normal pulmonary examination, GCS above 13, and required supplemental oxygen for no longer than 8 hours suffered no

decompensation during their hospital course.[68] Given the small but real chance for delayed pulmonary complications, it is reasonable that the asymptomatic submerged victim should be observed for a short period, 4-6 hours, in the emergency department. If the patient remains without signs of respiratory compromise, he or she can be discharged home safely.

Prevention

Primary prevention of drowning plays an important role in the safety of the general public. A 10-year study in pediatric patients showed that inadequate supervision existed in approximately 90% of drowning cases.[70] Often, brief lapses in supervision, such as the time it takes to make a phone call or tend to household chores, leave enough time for a drowning incident to occur. Leaving the supervision of a child to other children such as peers or siblings provides another common scenario of drowning. Infants commonly drown in bathtubs and even large buckets full of water and toilets, so counseling parents about close supervision in these settings proves important.[70,71]

Older children and adults more often drown in pools and open bodies of water.[4] Lifeguards supervising swimming environments contribute to safety while swimming.[72] In addition, floatation devices such as life jackets appear to help.[4] As mentioned before, uncertainty exists regarding whether swimming ability helps prevent drowning, since stronger swimmers tend to expose themselves to more dangerous swimming conditions.[71] Finally, avoidance of alcohol and stricter alcohol laws while swimming or boating promote safety.[4,10]

Fencing surrounding swimming pools provides the most evidence-based prevention of drowning. Ideal fencing consists of complete four-sided fencing that entirely surrounds the swimming pool separate from the home. Chain-linked fencing allows more ease in climbing, while ornamental iron bar fences are ideal because they are difficult to climb but do not obstruct visibility.[71] The U.S. Product Safety Commission recommends that fences stand at least 48 inches high and be built narrow enough so that children cannot put their feet through the fence. Gates should be self-closing and self-latching and should open outward, away from the pool, so that if a child pushes against the gate, it will close instead of open.[72]

Summary

Drowning is a process of respiratory impairment as a result of submersion in a liquid medium. All ages drown, but children are disproportionately likely to be involved in a drowning incident, which can occur in any open water, including bathtubs, toilets, and lakes. Initial stabilization of the drowned patient follows that of other critical patients, paying strict attention to airway, breathing, and circulation and following traditional ACLS protocols.

The breadth of pathology and severity of injury in the drowned patient is wide, and drowning should be considered a multi-system disease. Pulmonary injury is common, but deleterious effects are seen in the nervous, cardiovascular, renal, and other systems. Many patients will require ICU resuscitation. For the asymptomatic submerged patient, emergency department discharge is reasonable after a short (6-8 hour) ED observation. For patients with mild symptoms or requiring oxygen, a short inpatient stay is warranted.

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Physician CME Questions

11. According to published data, in the United States, which of the following characteristics is associated with higher incidence of drowning?
    A. adult age group
    B. female sex
    C. swimming in a supervised pool
    D. history of epilepsy

12. A 5-year-old patient is brought to the ED pulseless and apneic after a prolonged submersion. During the drowning process, which of the physiologic responses likely occurred?
    A. tachycardia upon initial submersion in water
    B. vasodilitation to preserve blood flow to peripheral muscles
    C. direct damage to lung tissue from aspirated water resulting in hypoxemia
    D. persistent laryngospam resulting in "dry drowning"

13. A 17-year-old girl is brought to a shallow area of a pool. She is pulseless and found to be in ventricular fibrillation. Important considerations for her resuscitation include:
    A. Defibrillation is contraindicated in a wet environment.
    B. Spine immobilization should be used.
    C. Airway, breathing, and circulation remain the initial priorities of resuscitation.
    D. Witness accounts of the event are of little importance in drowning episodes.

14. A 7-year-old boy is brought to the ED after a prolonged submersion in a pool. He is obtunded and in respiratory distress. His temperature is 95.7; pulse 115; blood pressure 115/75; respiratory rate 42; O_2 saturation 90% on a non-rebreather mask. Lungs sounds demonstrate diffuse crackles. Chest x-ray shows bilateral infiltrates. Regarding management of this patient, the EP should consider:
    A. immediate administration of antibiotics
    B. initiating large-volume fluid resuscitation
    C. aggressive re-warming measures
    D. placing a definitive airway for respiratory support

15. After successfully resuscitating a 9-year-old girl from a drowning event, the EP should consider the following when discussing prognosis to the family:
    A. Mild hypothermia from cold water drowning will worsen the clinical course.
    B. Submersion time of greater than 5-10 minutes is associated with worse outcomes.
    C. The patient likely will suffer large fluid and electrolyte shifts as a consequence of drowning.
    D. Antibiotics will prevent the development of pneumonia.

16. A 15-month-old boy is brought to the ED after a brief (< 1 min) submersion injury in a bathtub. Upon removal, the patient coughed briefly but did not require rescue breathing. In the ED, the patient appears comfortable with normal vitals and physical examination. The appropriate disposition for this patient is:
    A. immediate discharge from the ED if chest x-ray is normal
    B. inpatient admission regardless of ED course
    C. discharge to home if asymptomatic after a 4- to 6-hour observation period in the ED
    D. ICU admission and oxygen by nasal canula

17. Primary prevention plays an important role in limiting the number of deaths from drowning. Which of the following provides the best protection against drowning incidents?
    A. fencing around swimming pool
    B. swimming ability
    C. supervision of young child by siblings
    D. drinking in moderation when operating a personal watercraft

18. A 27-year-old man is ejected from a boat during a collision with a pier. Regarding the pre-hospital management of this victim:
    A. The Heimlich maneuver is necessary to remove aspirated material.
    B. Bystander-initiated CPR has not been shown to improve clinical outcomes.
    C. ACLS resuscitation should begin as soon as the rescuer can safely do so.
    D. Cervical spine injuries are very common in drowning incidents.

19. A 3-year-old girl is brought to an ED after a drowning episode. From an epidemiologic perspective:
    A. The drowning most likely occurred in a bathtub.
    B. Drowning accounts for 30% of the unintentional deaths in this age group.
    C. Females are more likely to be involved in drowning deaths than males.
    D. Drownings are more likely to occur during the winter months.

20. A 57-year-old man is brought to the ED after a prolonged submersion and resuscitation time. He is intubated without sedation for respiratory support. He has an abnormal pupillary response and shows no spontaneous movements. Regarding the pathophysiology of the disease process in this patient:
    A. Aspiration of large amount of water must occur to produce lung damage.
    B. Dilutional anemia and electrolyte abnormalities are likely.
    C. Traumatic brain injury, not anoxic insult, causes the majority of neurologic manifestations of drowning.
    D. Concomitant cardiac disease heightens the risk of dying from drowning.

CME Answer Key

11. D; 12. C; 13. C; 14. D; 15. B; 16. C; 17. A; 18. C; 19. B; 20. D

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