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Review

Drowning incidents precipitated by unusual causes (DIPUCs): A narrative review of their diagnoses, evaluation and management

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Abstract

Drowning is a cause of significant morbidity and mortality worldwide. In most circumstances, the proximate cause is attributable to human factors, such as inexperience, fatigue, intoxication, or hazardous water conditions. The phenomenon of drowning incidents precipitated by unusual circumstances (DIPUCs) – either fatal or nonfatal – involving otherwise healthy individuals under generally safe conditions has not been comprehensively addressed in the medical and drowning literature to date. In this review, we discuss etiologies of DIPUCs, diagnostic clues, suggested workup, suggested postmortem testing, and implications for surviving patients and families. Identifying the cause of a drowning incident can be extremely challenging for the initially treating physician, relying perforce on historical context, environmental clues, physical exam, medical history, eyewitness accounts or video recordings. If no clear explanation for a drowning incident emerges despite a thorough investigation, clinicians should consider some of the less common diagnoses we describe in this paper, and, when appropriate, refer for an autopsy with postmortem molecular genetic testing. While time-consuming, these efforts can prove life-saving for some non-fatal drowning victims and the families of all victims of DIPUCs.

Keywords: Drowning, Cardiac arrest, Accidental death, Health disparities, Injury science, Cardiomyopathy

Introduction

Despite an observed decrease in global drowning rates[1], drowning remains a leading cause of significant morbidity and mortality worldwide and is the third leading cause of unintentional injury deaths globally.[2] In this paper we use the term 'drowning' as defined by the World Health Organization (WHO), which is "the process of experiencing respiratory impairment from submersion/immersion in liquid."[2] The paper addresses fatal and non-fatal drowning; the WHO has developed a classification system for the latter.[3] This WHO report further asserted that the outcomes of a drowning incident should be classified as death, morbidity, and no morbidity. Adjectives that modify the term "drowning", such as "near", "wet" and "dry" are considered obsolete and will not be used in this paper; rather we shall use an accepted descriptor, "drowning incidents", as used by authorities, including the WHO, in the drowning literature.[3,4,5].

While we understand a great deal about the common causes of drowning, the recognition of uncommon etiologies, less well studied, is equally important for prevention strategies. In this paper we shall discuss the various mechanisms leading to a DIPUC, or a "drowning incident precipitated by an unusual cause", which we define as "a drowning incident not readily recognized or not commonly suspected as a result of human or environmental factors that usually accompany drowning incidents." Some examples of non-DIPUC drowning incidents would involve an individual seen diving into shallow water leading to a critical head or cervical spine injury, a swimmer struck by a moving aquatic vehicle, fall into the water from a significant height causing polytrauma, or the drowning death of an individual who is known to be unable to swim. For the purposes of this review, we are seeking to highlight causes of drowning in which an individual dies in the water without an evident situational cause. A DIPUC may require additional history, laboratory investigation, and field investigation to establish a probable diagnosis.

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The aim of this narrative review is to discuss, briefly, some of the many causes of DIPUCs and their importance to treating physicians, persons experiencing drowning incidents and possibly their families. Many of these causes are of particular interest to practitioners practicing wilderness and environmental medicine, e.g., aquatic animal injuries, white water sports, self-contained underwater breathing apparatus (SCUBA) diving and open water swimming. There are no similar narrative reviews that the authors have identified and the only two papers that have reviewed many disparate medical causes of drowning did not examine many of the non-medical causes we discuss in this paper.[6,7] An overview of the many etiologies of DIPUC is summarized in Table 1.

Methods

We searched Embase, Google Scholar, PubMed and Scopus for any English-language papers, primary studies or case reports or related articles, published between January 1985 and March 2024 using permutations of the term "drowning" AND the various causes and associations described in this paper (see Table 1), e.g., "drowning AND ARVD", "drowning AND QTc prolongation", et cet. In addition, we pursued relevant references in the citations of papers we found useful during the search. We excluded publications not in English, many duplicates, papers strictly related to treatment, and papers not including uncommon causes of drowning. We identified 351 papers

Table 1 – DIPUC's: selected etiologies, associations and diagnostic clues.

Category	Examples		Possible historical clues	Possible physical exam clues	Possible laboratory clues
Environmental	Physical injury		Detailed timeline, eyewitness	Traumatic injury patterns	Autopsy
	Electricity		Eyewitness; investigation of the scene	Burn wounds	Elevated muscle damage markers, burns, autopsy
	Aquatic animals		History of dangerous aquatic animals in the area; eyewitness	Animal injury patterns	Autopsy
Behavioral	Drugs/alcohol when not suspected		History of use	Injection site wounds	Blood ethanol level, Toxicology screen
	Hypoxic ("shallow water") blackout		Context, eyewitness		
	Panic		Context, eyewitness		
	Suicide/homicide		Context Mental health history Witnesses, video, suicide notes	Injury patterns (past [child abuse] and present)	Toxicology screen, autopsy
Physiologic	Cold-water and exercise-induced ischemia		Detailed history		ECG, Troponin
	Autonomic conflict		Context of cold water		
	Immersion Pulmonary Edema		Context, dyspnea	Rales	ECG, Ultrasound, Xray, Autopsy
Cardiac	Channelopathies	Brugada syndrome	Detailed history Family history of sudden cardiac death, especially in cold water	none	ECG, echocardiogram, cardiac imaging, ambulatory monitoring, genetic analysis, molecular testing autopsy
		Short QT syndrome			
		Long QT syndrome			
	Structural	Anomalous coronary artery, ARVD/C, CPVT	History of syncope		
Seizures	Epilepsy		Detailed history Family history	Post-ictal confusion, Tongue biting, dislocated shoulder	Molecular testing, elevated muscle damage markers, elevated prolactin

ARVD/C: arrhythmogenic right ventricular dysplasia/cardiomyopathy.
CPVT: catecholaminergic polymorphic ventricular tachycardia. ECG: electrocardiogram.

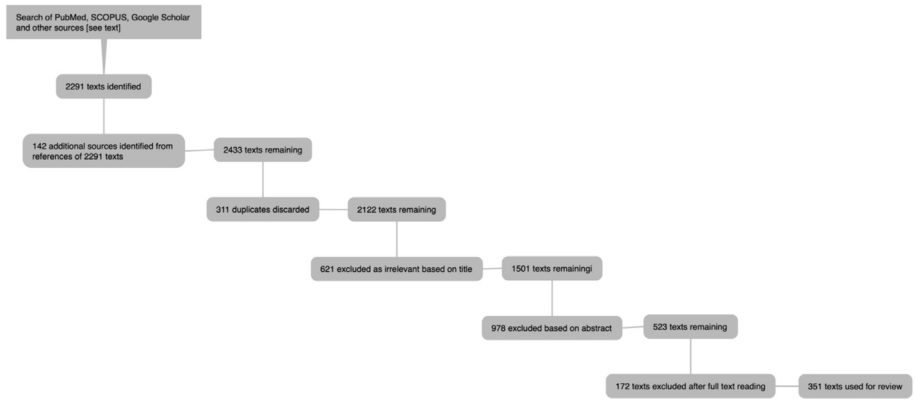

Fig. 1 – Reference Harvesting.

that met inclusion criteria of the search and satisfied our definition of a DIPUC as defined above and also represented an etiology frequent enough to generate several references. We did not include extremely rare etiologies, e.g., swimming pool entrapment[8]. We also reviewed pertinent articles, papers and online resources by the World Health Organization, the U.S. Centers for Disease Control and Prevention, the U.S. National Weather Service and U. S. newspapers in Google Books and ProQuest. (See Fig. 1).

Environmental causes

Physical injuries

Although physical injuries are well recognized as unfortunate events in swimming and diving[9], such injuries are an uncommon cause of DIPUCs since most physical injuries significant enough to cause a drowning incident, especially injuries from SCUBA diving or competitive diving, are usually evident at the time of injury. In one study of swimming injuries treated in U.S. emergency departments (EDs) from 1990 to 2008, only 255, or 0.6 %, of 41,242 injuries were fatalities.[9].

Electrical injuries

Although an infrequent cause of DIPUCs, electrical injuries can occur from in-water exposure to electrical current or a lightning strike. The former can occur when an individual touches an energized conductive object outside the water or approaches an electric field in the water, such as a boat or dock connected to an on-shore power source. Persons who survive face organ damage, including acute renal failure from rhabdomyolysis, which is often followed by laboratory markers, e.g., creatine kinase and myoglobinuria.[10,11] Lightning accounts for approximately 27 deaths per year in the United States, most of which involve water-related activities, with 8 % associated with swimming.[12,13] In one study, children represented almost half of those receiving electrical shocks in swimming pools.[14] Since the cooling effect of surrounding water may obscure the usually evident entry and exit points of the electrical current on the victim's body, the differentiation of electrocution from drowning can be difficult for the pathologist.[15].

Aquatic animals

Drowning from interactions with aquatic animals is uncommon since they and humans prefer to avoid each other. The venom from the box jellyfish, especially *Chironex fleckeri*, can be lethal, causing cardiopulmonary arrest within minutes, most commonly in children, but almost never death by drowning.[16] Similarly, envenomation by sea snakes (Elapidae family) is rare, with no reports of drowning deaths in the literature. Crotaline snakes, such as copperheads or rattlesnakes, have also rarely caused a DIPUC, with only one drowning death reported.[17] Stingrays are usually not aggressive towards humans but can, infrequently, lead to severe consequences, such as in the death of Steve Irwin, star of the show "The Crocodile Hunter", who died from the physical piercing of his thoracic wall and heart by the tail of a short-tail sting ray (*Bathytoshia brevicaudata*).[18] Crocodilians (crocodiles, alligators, caimans) cause death by seizing the victim with powerful jaws and submerging it.[19] Unlike most DIPUCs, this cause is not occult when witnessed but may be the explanation for a missing person near bodies of water inhabited by crocodilians.

Behavioral causes

Intoxication

Intoxication is a major contributor to drowning incidents, particularly among adults engaging in recreational activities in the water, especially men aged 18–64.[20] [40][43] In a systematic review of English language studies published up to October 2003, Driscoll et al. found that 30–70 % of drowning victims had had positive blood ethanol levels.[21] One review found that 49.46 % of fatal drownings and 34.88 % of non-fatal drownings of any kind involved alcohol consumption.[20] In addition to alcohol, intoxication with other psychoactive substances was also associated with 91.7 % of fatal suicide drowning incidents in Australia.[22] Despite its ubiquitous presence in many drowning studies, we include it not as an uncommon or unusual contributing factor but only in so far as when it is not suspected.

Hypoxic blackout

Hypoxic blackout, colloquially referred to as "shallow water blackout" and DUBB (dangerous underwater breath-holding behavior)[23], is a phenomenon that can lead to drowning in otherwise physically fit, even elite, swimmers[24] and occurs in both shallow and deep water.[25] It usually occurs during breath-holding training, competition races, and endurance events such as underwater swimming and diving. The mechanism is thought to be pre-immersion hyperventilation with an hypoxic loss of consciousness occurring before protective CO_2 chemoreceptors can stimulate breathing.[26].

Panic

Approximately 80 % of triathlon deaths occur during the swimming portion, with panic thought to be one of the major contributors[27], along with immersion pulmonary edema (see below).[28] The open water swimming portion of triathlons can be chaotic and anxiety-inducing since most triathletes have only trained in pools prior to the open water swim. The crowded setting of the actual race can quickly lead to panic, possibly producing a sympathetic surge that can exacerbate the potential for any underlying dysrhythmias and activate the autonomic conflict discussed below. Panic is also a well-recognized risk factor for drowning in SCUBA diving[29], and can lead to a divers irrationally removing her regulator and face mask and then drowning, the true cause of which may not be easily ascertainable.

Suicide

Suicide is an unfortunate but common etiology of DIPUCs.[30–32] In one 13 year retrospective South Korean review of 380 patients who presented to their hospital with drowning incidents, 282 (74.2 %) drowned intentionally.[33] In another review of intentional drowning incidents in Australia from 2007 to 2018, risk factors for intentional drowning were older age, testing positive for psychoactive substances, and female gender.[34] This last risk factor, female gender, has been a constant over the decades.[35–37].

Homicide

There is very little literature on the statistics of adult or childhood homicidal drowning. Although most childhood drowning is accidental, children are, unfortunately, much more likely to be the victims of homicidal drowning than adults.[38] Kemp et al. posit that a diagnosis of child abuse “should be considered in the differential diagnosis of atypical bathtub immersions in the absence of epilepsy and developmental delay.”[39].

Physiologic causes

Autonomic conflict and the cold shock and diving responses

Submersion in cold water (<15° C) with breath-holding causes two simultaneous responses: the “cold shock response” and the “diving response”. The former, mediated by cutaneous cold thermoreceptors, elicits a sympathetic stimulation with resultant tachycardia, as well as a respiratory gasp, hyperventilation, peripheral vasoconstriction and hypertension.[40] In contrast, the diving response, which only occurs with facial immersion[41], elicits a parasympathetic response with subsequent bradycardia, an expiratory apnea and sympathetically driven vasoconstriction in the trunk and limbs—all allowing the organism to conserve oxygen during a longer dive time.

Shattock and Tipton hypothesize that this simultaneous co-activation of both limbs of the autonomic system[42] results in an autonomic conflict that can explain the dysrhythmias precipitated by cold water immersion.[41] The same autonomic conflict in an older person can produce, additionally, a potentially more dangerous cascade of consequences. The transient tachycardia and greater oxygen demand, in the presence of atherosclerotic coronary disease, can lead to coronary ischemia rendering the heart even more vulnerable to an infarct and arrhythmias.[41].

Pulmonary Edema

“flush” drowning

Another DIPUC is known colloquially as “flush drowning” in white water sports, i.e., an unexpected drowning – often in high flows or cold water – not readily explainable by one of the common causes of white water drowning, e.g., prolonged underwater entrapment or trauma.[43] As Sempsrott et al. clarify, however distinct the phenomenon or whatever the etiology, “it would be more appropriate to describe these events as ’fatal drowning caused by’ or ’nonfatal drowning associated with’ and then use the whitewater-specific term as needed.”[44].

Immersion pulmonary edema (IPE)

Immersion pulmonary edema (IPE) is a broad term that encompasses several distinct but related entities characterized by pulmonary edema originating in the water, usually cold water and usually during exertion: “swimming-induced pulmonary edema” (SIPE), “scuba divers’ pulmonary edema” (SDPE)[45] and SIROPE (snorkeling-induced rapid onset of pulmonary edema).[46].

SIPE tends to occur more commonly in men in excellent physical condition without any comorbidities, e.g., military or combat swimmers and triathletes undergoing physical exertion.[47] SDPE, however, occurs more often in women of middle age who are engaging in recreational swimming. Comorbidities, e.g., hypertension and ischemic heart disease, are more common in SDPE.

Snorkeling induced rapid onset of pulmonary edema (SIROPE or ROPE)

Snorkeling within several days of a long haul (≥6 h) airplane flight, e.g., international flights to Hawai’i, has been identified as a risk factor for fatal pulmonary edema.[46] This state-sponsored study discovered that 46.3 % of visitors to the island die from ocean drowning as opposed to only 4.1 % of Hawai’i residents. Indeed, snorkeling accounts for 26 % of visitor deaths while swimming is responsible for 20 %. The authors of this study hypothesize that the pressurized cabin air of the airplane alters the vascular permeability of the alveolar circulatory bed rendering it more vulnerable to the negative transthoracic pressure created by snorkel-breathing and subsequent pulmonary edema, the pathological finding in snorkel-related deaths in Hawai’i.

Since, pathologically, pulmonary edema from non-IPE drowning is indistinguishable from the pulmonary edema commonly found in swimmers or divers who come to autopsy after drowning as a result of any cause of IPE[48], the diagnosis can be difficult to establish by autopsy alone.[49] Pulmonary edema from IPE is, therefore, an invisible diagnosis hiding in plain sight from a pathologist.

Syncope and death by hot water bathing

Syncope is another DIPUC, particularly in the elderly, and especially in hot water baths. In Turkey, balneotherapy (treating disease by bathing in mineral waters) has been associated with death and drowning.[50] Yang et al., in a nationwide study of 84 cases of bath-related deaths in Korea from 2008 to 2015, found that drowning was the primary cause of death in two thirds of the deaths.[51] In this series, the two leading contributory causes of bath-related deaths were cardiovascular diseases and binge alcohol drinking before bathing, leading to loss of consciousness and drowning.

The practice of hot water bathing in shoulder high tubs is popular in Japan where the Tokyo Fire Department has estimated that 14,000 deaths per year occur during bathing.[52] Nagasawa et al. report that the risk of sudden death while bathing is approximately 10 times higher than during sleep.[53] This increased risk of bathing death is multi-factorial: elderly subjects studied in a bath of 42 °C for 8 min displayed increased heart rate and decreased blood pressure signifying increased workload on the heart and lower coronary perfusion.[54] A decreased perception of cold and heat[54], along with the presence of ventricular arrhythmias in the elderly[55], and an increased risk of syncope[53], explain the risky nature of Japanese style bathing, especially in the elderly and in Winter. Sauna, often combined with alcoholic beverages, has also been associated with drowning.[56].

Cardiac causes

Channelopathies

Cardiac channelopathies are defects – genetic or acquired – in cardiac ion channels.[57] In this section we briefly discuss the channelopathies most commonly associated with drowning events.

Short QT syndrome

Although a short QT syndrome (SQTS) may predispose to premature mortality[58], it is quite a rare finding. We identified no reported cases to date of a drowning caused by SQTS. Therefore, we shall focus only on drowning and a long QT interval.

Long QT syndrome (LQTS)

Some channelopathies, especially those involving repolarization and therefore the QT interval, can be pro-arrhythmic. The QT interval is an indication of the duration of repolarization. Since the QT interval varies with heart rate, age, and gender, an accepted standardized proxy for the QT interval is the corrected QT interval (QTc), which estimates the QT interval at a standard heart rate of 60 beats per minute.[59] The arrhythmias produced by the alterations in the QT interval are especially important risk factors for sudden cardiac death (SCD).[60].

A prolonged QT interval may arise from a variety of causes, i.e., congenital, metabolic, hematologic[61], or drug-induced.[62] Regardless of the cause, a long QT interval can predispose to lethal arrhythmias since a prolonged repolarization offers more opportunity for an early after depolarization to lead to an arrhythmia and SCD.[63,64] Winter et al. have demonstrated that the cold water-induced autonomic conflict discussed above may also exacerbate the long QT syndrome.[65].

Congenital long QT syndrome (cLQTS)

Congenital Long QT syndrome (cLQTS) is an inherited disorder with a prevalence of approximately 1:2000.[66] There have been many different genes associated with cLQTS.[67] LQT1 – the most common type of cLQTS, caused by a loss-of-function mutation in the KCNQ1 cardiac voltage-gated potassium channel – is strongly associated with cardiac events during exercise.[68] Swimming, specifically, has been associated with syncope and arrhythmogenesis, including drowning, in cLQTS.[69–72] In one retrospective study, swimming was a trigger of a cardiac event such as torsades des points (TdP) in 33 % of individuals with known triggers and LQT1, and, within a group of patients who had had a cardiac event while swimming, 99 % had the LQT1 mutant subtype.[73].

Choi et al.[74] hypothesize that swimming can be an arrhythmogenic trigger for several reasons: first, the "exertion, voluntary apnea, possible cold-water exposure, and face immersion" summon the "dive response" that includes both sympathetic and parasympathetic activity; second, cold-water face immersion may lead to increased QT intervals.[75]; third, epinephrine has been shown to produce a paradoxical prolongation of the QT interval.[76] Additionally the "autonomic conflict" discussed above may contribute to SCD via cLQTS.[41].

Metabolic causes of a prolonged QTc

A prolonged QTc interval can also transiently occur, secondary to metabolic derangements, in people without a genetic predisposition. Some of the more common causes for a metabolically prolonged QTc interval are hypocalcemia, hypokalemia and hypomagnesemia. In the setting of hypothermia, induction of serum hypokalemia is accompanied by an increase in intracellular calcium. The intracellular hypercalcemia is felt to the most likely driver of cardiac dysrhythmias in this situation. [77] Although hypothermia[78] and hypocalcemia, whether secondary to hypoparathyroidism or other causes, can lead to arrhythmias, including torsades des pointes[79], we could find no reports of drowning related to a prolonged QT interval secondary to electrolyte abnormalities.

Drug-Induced long QT syndrome (DILQTS)

QTc prolongation is associated with a variety of medications and is known as drug-induced LQTS (DILQTS) or medication-induced QT prolongation (MIQTP).[80] Drugs that can cause QTc prolongation include class Ia and class III anti-arrhythmics, atypical antipsychotics, antidepressants, neuroleptics, anti-emetics, antibiotics, and methadone.[62] Vincenzi et al. reported a fatality in a SCUBA diver that was attributed to DILQTS.[81] The diver developed a dysrhythmia during descent, was found to be in ventricular fibrillation, but had unsuccessful on-board defibrillation. At postmortem she had a supratherapeutic level of citalopram in her blood.

Brugada syndrome

Brugada syndrome (BrS) is an inherited channelopathy characterized by typical ECG morphologies, increased risk for arrhythmias, syncope and SCD.[82,83] Although there have been no case reports of drowning associated with BrS, one paper has suggested the possibility.[84].

Catecholaminergic polymorphic ventricular tachycardia (CPVT)

Catecholaminergic polymorphic ventricular tachycardia (CPVT), another channelopathy that has been associated, rarely, with drowning incidents[85], is a distinct channelopathy caused by gain-of-function mutations in the RyR2 gene, which encodes the cardiac ryanodine receptor.[86] These mutations produce a hyperactive channel, causing excessive spontaneous sarcoplasmic reticulum calcium release during sympathetic stimulation, subsequent calcium overload, and ventricular arrhythmias.[86] This cascade of events can be triggered by emotional or physical stress, exertion or bathing[85,87] and, although previously phenotypically silent[84], can lead to syncope or SCD.[88] In one study of patients who had had a drowning incident and were referred for LQTS-related genetic testing, nine of 43 had “novel, putative CPVT1-causing variants in RyR2 ... the near-drowning or drowning was the sentinel event in 8 cases.”[74].

Arrhythmogenic right ventricular Dysplasia/ Cardiomyopathy

Arrhythmogenic right ventricular dysplasia, now more commonly referred to as arrhythmogenic right ventricular dysplasia/cardiomyopathy (ARVD/C), can be caused by multiple genetic mutations that predispose young patients to ventricular tachyarrhythmias and SCD.[89] It is characterized by progressive replacement of the myocardium with fibrofatty tissue that disrupts electrical transmission leading to arrhythmias. This disruption occurs primarily in the right ventricle. As Patel et al. demonstrated, there is evidence that mutation in a common gene, RyR2, can lead to either–or both–CPVT and ARVD/C.[89].

Anomalous coronary artery

Coronary artery anomalies (CAAs) comprise a large group of diverse pathologies that can present in many different ways.[90] Although most are incidental, benign and of no clinical significance, some may present lethally, often at an early age. Although anomalous aortic origin of a coronary artery (AAOCA) is the most frequent cause of SCD among all coronary anomalies[91], there have been no reported drownings associated with it. Anomalous left coronary artery from the pulmonary artery (ALCAPA) is a rare condition that can cause a steal phenomenon resulting in myocardial ischemia. In one case report, an 11 year-old girl who had had a cardiac arrest while swimming was resuscitated and found to have an operable ALCAPA on transthoracic echocardiogram.[92].

Equally rare, and equally lethal, is the syndrome of right coronary artery originating from the left sinus of Valsalva. Bunai et al. present the case of an unfortunate 21 year-old woman with this anomaly who drowned in her bathtub.[93].

Myocardial infarction

The accurate distinction of a myocardial infarction as etiology versus a consequence of drowning is very difficult, whether by ECGs or other laboratory tests.[94] Attempts to make this distinction with biochemical markers postmortem have yielded mixed results.[95] One prospective French study found that sports-related acute cardiovascular events occurred in about 6.5 participants per 100,000 participants per year.[96] These were most common in middle-aged men, and swimming was the second most common activity performed during acute cardiovascular events. Since exercise can elevate high sensitivity troponin T, the use of troponin assays alone to differentiate between myocardial infarction as a cause or a result of drowning can be complex.[97].

Seizures

Seizure disorders are among the leading causes of drowning worldwide. Since part of the definition of sudden unexpected death in epilepsy (SUDEP) is the exclusion of drowning[98], and since the differentiation between SUDEP in water versus epilepsy-related drowning without SUDEP is a distinction without a difference[99], we shall not include SUDEP in our discussion of a DIPUC.

At any given time, the risk of drowning is significantly higher in persons with epilepsy (PWE) compared to the general population. In a literature review of 51 cohorts of data, the standardized mortality ratio of drowning for PWE was 18.0.[100] In another study using data from 1974 to 1990, it was calculated that children with epilepsy have a relative risk equal to 47 for submersion in a bathtub compared to children without epilepsy, and 18.7 in a pool.[101] The relative risks of drowning in a bathtub and pool are even higher: 96 and 23.4, respectively. Even showering can be dangerous for PWE. Nakagawa reported the drowning death while showering of a 25 year old woman who had been nonadherent with her antiepileptic medications.[102].

Indications to suspect A DIPUC

There are no definite criteria to suspect a DIPUC. Table 2 lists scenarios that should prompt emergency medicine providers (EMPs) to consider the possibility of further investigation – from scene investigation to law enforcement to laboratory testing, e.g., genetic testing and an autopsy with molecular autopsy.[103,104] The driving stimulus to suspect a DIPUC is the EMP wondering why someone drowned when the context raises common sense questions about an uncommon event, and the EMP trusting her experience and listening to her instincts to probe more into causation. [105].

Management of A DIPUC

Role of the Healthcare team

The approach to a DIPUC is often a team approach involving first responders, EMPs, pathologists, geneticists, cardiologists and sometimes psychiatrists and law enforcement. Every attempt should be made to discuss the case with first responders and eyewitnesses and ensure that the history is accurately entered into the medical

Table 2 – Specific scenarios which should raise concern for DIPUC.

Unusual circumstances	Past medical or psychiatric history	Past cardiac history
Strong swimmers experiencing drowning, especially in non-challenging water conditions	Personal history of syncope	Family history of sudden death (especially during exertion or swimming)
Brief duration of swimming arguing against exhaustion	Suspected or known psychiatric history, especially suicidal ideation	Personal or family history of cardiomyopathy
Apparent DIPUC in shallow water	Suspected or known substance abuse history	Patients on QTc-prolonging medications

record. Given the lack of reliable physical signs, laboratory tests and postmortem findings for a definitive diagnosis of many causes of DIPUCs, history, as it is in the diagnosis of syncope, is paramount.[106].

Drowning patient lives

After a history including first responders and their report of the scene, a physical exam, ECG, chest radiograph, and toxicologic screening, especially a blood alcohol level (particularly in men), should be obtained. If there is a concern for seizure, these patients should receive a seizure workup, advice about unsupervised risky activities including any form of unsupervised bathing, and proper neurological follow-up.

Suspecting a channelopathy is important with several caveats. Relying on family history alone can lead to false negative conclusions since affected relatives may still be phenotypically silent.[107] There are several false positive diagnoses of LQTS reported.[108] Nevertheless a careful history and an ECG are essential. If the suspicion is strong enough, the provider may cautiously suggest a cardiologic evaluation, especially before any exertion or exercise, especially swimming. The EMP should attempt to provide the most appropriate follow-up, e.g., cardiology (optimally a cardiologist with genetics expertise, if one is available[109]), genetics or neurology.

Drowning patient dies in the ED

If a patient is pronounced dead in the emergency department, as much history as possible should be obtained from first responders and family. If the EMP suspects a DIPUC (see Table 2), relevant information (see Table 1), including an autopsy, is essential. If the EMP strongly suspects a genetic cause from history or ECG, she should request the medical examiner to obtain DNA for a molecular autopsy, i.e., evaluation for channelopathies including LQTS and CPVT[85] to identify vulnerable family members for counseling.[109].

Limitations

The literature on the disparate etiologies of DIPUCs is characterized, for the most part, by case reports with few prospective studies of their individual or group statistical contribution to the significance in drowning, either chronologically or regionally. Therefore, inferences about DIPUCs remain an imprecise set of likelihoods rather than precise facts or patterns. Also, given their often subclinical presentations in an injury that has, as a final common pathway, a pathologic state that remains a potentially confusing and difficult diagnosis for the pathologist at autopsy[110], they are most likely under-reported, especially since they are not included as specific diagnoses in some registries of drowning, e.g., the CDC[111] and the Utstein-style consensus conference on drowning.[112].

In this narrative review we attempt to provide a clinically relevant summary of what we believe to be the most pertinent but ultimately limited data available on this topic. As this is not a systematic review, there may be data which we have not identified for this paper, and generating recommendations or guidelines is outside the scope of this paper. Furthermore, quantitative analysis or synthesis of the data (i.e. meta analysis) contained in the cited studies was not performed nor was a formal analysis of potential sources of bias in the cited sources undertaken.

Conclusion

Drowning remains one of the most common causes of morbidity and mortality worldwide. Unfortunately, the existing literature we surveyed does not comprehensively address the ubiquitously occurring but uncommon precipitating causes of drowning (DIPUCs) that we have discussed in this paper. These unusual precipitants should be in the differential diagnosis for emergency medicine physicians and pathologists confronted with a possible DIPUC since the correct identification of some DIPUCs can lead to life-saving guidance and screening of other equally vulnerable family members.

CRediT authorship contribution statement

Kevin M. Duignan: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Hannah Luu:** Writing – review & editing, Writing – original draft, Resources, Investigation. **João H. Delgado:** . **Shawn London:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Richard M. Ratzan:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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