Drowning and Near-drowning-Some Lessons Learnt

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Abstract

Over a period of sixteen months, 17 cases of submersion injury (encompassing victims of drowning and near-drowning) were attended to at our Accident and Emergency Department at Changi General Hospital. Most of the victims were inexperienced recreational swimmers, and in 6 of them, early bystander cardiopulmonary resuscitation enabled them to recover without severe morbidity. Non-cardiogenic pulmonary oedema with resulting chest infection was the commonest complication in survivors. Most of the episodes occurred in an urban setting in swimming pools without supervision by lifeguards. About two-thirds of the cases were adults over the age of fifteen years. In addition, there werepatients in whom submersion injury was associated with more sinister conditions (fits, traumatic cervical spine injury, dysbarism, intoxication from alcohol or drugs), some of which were unsuspected by the doctors initially. Apartfrom the immediate threats of hypoxia andpulmonary injury, active search for anypossibleprecipitating causes and associated occult injury should be made. In this study, the determinants of survivalfrom near-drowning were early institution of cardiopulmonary resuscitation, presence ofpupil reactivity, and presence of a palpable pulse and cardiac sinus rhythm.

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Introduction

Drowning is defined as suffocation from submersion in a liquid with death within the first twenty-four hours. Near-drowning implies that recovery has occurred, at least temporarily, or that the victim has survived over twenty-four hours.' Drowning and near-drowning accidents are also described by other synonyms such as immersion accidents and submersion injury. They are a less common cause of environmental injury here in Singapore as compared to those injuries from heat injuries, animal bites, and envenomation by poisonous creatures. Nevertheless, they are more often encountered in certain hospitals in Singapore. Such is the case at Changi General Hospital, which is near to the seaside recreational areas sited at and around the East Coast Park, Changi Beach and Pasir Ris Beach. The hospital also serves housing estates in its vicinity, and many of these estates have swimming pools on their premises.

A study of victims of drowning and near-drowning presenting to the Accident and Emergency Department over a period of 16 months, from the time of the hospital's inception until the present. We studied the spectrum of submersion injuries, the profile of the swimmer-at-risk, and also identified certain uncommon but important causes of submersion injuries. Factors indicating the likelihood of a good recovery outcome were also studied.

Materials and Methods

Over a period of 16 months, from March 1997 to June 1998, all patients with submersion injuries that presented to our Accident and Emergency Department were recruited into this study. The patients' biodata were obtained, and we also inquired about their capability to swim, either from the victims or relatives and friends. This was necessarily subjective, as there is no standard criteria by which we could judge the ability to swim, and because of the large amount of observer variability. Whether any bystander CPR was performed was also noted. Any precipitating causes for their drowning were identified as far as possible. Treatment such as the need for endotracheal intubation, cardiopulmonary resuscitation, and correction of electrolyte abnormalities were also identified. The neurological findings at the time of presentation were studied. These consisted of indicators of neurologic function such as pupil reactivity, and also the state of consciousness at presentation. We also reviewed the chest X-ray findings at presentation and any respiratory complications from the drowning episode. Lastly, the type of drowning (whether salt or fresh-water drowning) was noted.

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Results

Seventeen patients were encountered during the study period, of which 14 were male. Their ages ranged from 8 to 50 years, with a mean of 23.8 years. Only 5 were under the age of 15 years. The majority were swimming for leisure when they encountered difficulties. Seven of the 17 patients were graded as experienced swimmers, based on their own feedback or feedback from relatives or friends (for this survey, this was unavoidably a subjective answer for most patients). The circumstances surrounding the drowning episodes, any eyewitnesses, the need for CPR, and availability of CPR are all summarised in Table I.

Of the 8 patients who received CPR (4 were initially apnoeic, and 4 were apnoeic and pulseless), 6 were immediate. These 6 patients survived neurologically intact (included 2 who were pulseless as well as apnoeic). Five of the 6 patients recovered to the extent that they were alert and could breathe on their own by the time the ambulance officers arrived.

The 2 patients who received delayed CPR had fatal outcomes. One was a boy who was found missing during a class outing by the sea. He was found after a prolonged search; CPR was therefore delayed. The other drowned in a private swimming pool, and there was no immediate CPR provided, this being started only when the ambulance officers arrived on scene. Both drowning episodes were not witnessed, and it could be that they were submerged for prolonged periods. Both were brought to the Accident & Emergency (A&E) Department pulseless, without spontaneous respiration, or pupil reactivity. They were inventricular fibrillation and asystole, respectively (Table II). They failed to respond to resuscitation at the A&E department.

TABLE I: CIRCUMSTANCES OF SUBMERSION INJURY IN VICTIMS

	Occurred at sea	Occurred at public pools	Occurred at private pool	Number
No. of cases	6	6	5	Total = 17
No. of witnessed drowning cases	5	6	4	Total = 15
No. not needing CPR	4	1	3	Total = 8
No. needing CPR (and presence of pulse or respiration)	2: - 1 apnoeic - 1 apnoeic & pulseless	5: - 3 apnoeic - 2 apnoeic & pulseless	2: - 2 apnoeic & pulseless	Total = 9
Any CPR received	1 immediate, 1 delayed	5 immediate (by life-guards)	1 delayed, 1 no CPR received	Total = 8 received CPR, 6 immediately

TABLE II: FACTORS AFFECTING OUTCOME OF PATIENTS

S/N	Age	Initial conscious state	Initial A&E cardiac rhythm	Initial spontaneous respiration	Immediate bystander CPR	Pupils	Neurologic outcome
1	21	Alert	Normal	Yes	Not needed	Reactive	Intact
2	19	Alert	Normal	Yes	Not needed	Reactive	Intact
3	8	Alert	Normal	Yes	Not needed	Reactive	Intact
4	21	Alert	Normal	Yes	Not needed	Reactive	Intact
5	30	Alert	Normal	Yes	Not needed	Reactive	Intact
6	32	Alert	Normal	Yes	Not needed	Reactive	Intact
7	43	Alert	Normal	Yes	Not needed	Reactive	Intact
8	31	Alert	Normal	Yes	Not needed	Reactive	Intact
9	20	Loss of consciousness few minutes**	Normal	No	Yes	Reactive	Intact
10	38	Unconscious*	Normal	No	Yes	Reactive	Intact
11	20	Loss of consciousness 5 minutes	Normal	No	Yes	Reactive	Intact
12	30	Loss of consciousness few seconds**	Normal	No	Yes	Reactive	Intact
13	13	Loss of consciousness few minutes	Normal	No	Yes	Reactive	Intact
14	10	Loss of consciousness few minutes	Normal	No	Yes	Reactive	Intact
15	9	Unconscious	Asystole	No	No	Unreactive	Hypoxic brain damage
16	50	Unconscious	Asystole	No	No	Unreactive	Died on arrival
17	11	Unconscious	Ventricular fibrillation	No	No	Unreactive	Died on arrival

* Was later diagnosed to have overdose of benzodiazepine, which would explain her inability to regain consciousness with CPR initially

** No pulse palpable when sought for by the initial CPR rescuer

One patient who did not receive CPR was brought in by private transport. He was a young child. who was swimming in a pool within a housing estate. On arrival, he was very ill, without pupil reactivity, a palpable pulse or spontaneous respiration. He was immediately intubated and resuscitated upon arrival. Although he responded to our treatment and survived, he suffered hypoxic brain damage and remained in a vegetative state in our medical intensive care unit for 10 days. Thereafter, his parents discharged him against our medical advice to another hospital.

For each patient, their pupil reactivity, need for bystander CPR, initial cardiac rhythm, spontaneous respiration and neurologic outcomes were listed in Table II. It would seem that at least 6 lives were saved with timely and early CPR. Early CPR helped to secure a good neurologic outcome in those 6 patients who were initially unconscious and apnoeic, and of which 2 were pulseless initially. Using pupil reactivity as a predictor of neurologic outcome has proved reliable in this series. Patients with normal cardiac rhythm upon presentation at the A&E department, and with only short periods of loss of consciousness also did well in terms of neurologic outcome.

We tried to find out the causes of the drowning episodes for each patient (Table III) whenever possible. Among the rarer, and sometimes unexpected, causes of near-drowning were associated benzodiazepine ingestion (part of a suicide attempt), cervical spine injury with resulting quadriplegia, alcohol ingestion and fits.

Case 1

This patient was found struggling in the sea. She was rescued by bystanders and CPR was given. Although she came to the A&E department with spontaneous respiration, palpable pulse and intact pupil reactivity, she remained unconscious, responsive only to painful stimuli. As she was fully clothed and not in swimwear, it did not appear that she was swimming for recreational purposes. Bystanders also gave a history that she appeared depressed and was crying before entering the water. A suspicion of suicidal intent was entertained, with possible drug overdose. She was given a challenge of intravenous flumazenil and subsequently awoke, when she then admitted to having taking an overdose of diazepam before attempting to drown herself.

TABLE III: CAUSES OF SUBMERSION INJURY

Cause of drowning / near-drowning	Number
Inexperienced swimmer	7
Leg cramps	2
Encountered difficulties in deep water	1
Cervical spine injury	1
Fits	1
Alcohol intoxication	1
Decompression sickness (naval diver)	1
Drug overdose and attempted suicide	1
Unknown (unwitnessed deaths)	2
Total	17

Case 2

The patient with a cervical spine injury was initially thought to be a victim of simple drowning only. He was intubated at the A&E department because of poor oxygen saturation and his chest X-rays showed severe pulmonary congestion. His blood pressure was also low, and this was thought to be due to his near-drowning. However, it was only in the medical intensive care unit several hours later that it was discovered that he had weakness of all 4 limbs, with a lax anal sphincter tone. Subsequently, a cervical spine injury was found (burst fracture of the sixth cervical vertebral body) on radiological studies. His low blood pressure was due to neurogenic shock. This was puzzling as the patient had not dived from any height, and was in fact found lying in water just 2 feet deep. It was only after the patient was extubated and could talk that a proper history was available. He had dived head first into the shallow water, and so struck his head against the bottom. The neck injury caused him to be paralysed in the water, and he nearly drowned.

Case 3

The patient with fits was a 13-year-old child, who had gone swimming with his uncle. He had no past history of epilepsy, but the day before the event, he had an episode of convulsions, which lasted a few minutes. He later recovered fully and as there was no sequela, his family did not bring him to see a doctor. On the morning of the event, he had another episode of fits, but again recovered fully. He was allowed to swim that afternoon, and was later found lying in the pool motionless. As he was a good swimmer and was unlikely to get into difficulties, it was believed that he had fits again while in the water. There were other people around who pulled him out of the water. He was intubated upon arrival at the A&E due to pulmonary aspiration and poor oxygen saturation, but his pupils were reactive and he was slowly regaining consciousness. He made a full recovery from the near-drowning episode. Subsequent investigations showed that he had an arterio-venous malformation in his left parietal lobe. He was placed on long-term phenytoin therapy, pending a decision by the family for neurosurgical intervention.

Case 4

The patient with alcohol intoxication had consumed 2 large bottles of beer before going swimming in the sea. He encountered difficulties in deep water, but was for-

tunately rescued by his relatives who was swimming with him. He was also intubated upon arrival at the A&E due to aspiration of sea-water and poor oxygen saturation, but his pupils were reactive and he was slowly regaining consciousness. He also made a full recovery from the near-drowning episode.

We also studied the initial biochemical and electrolyte profiles of the 15 patients that survived, to see if there were any abnormalities (Table IV). The initial blood tests drawn after arrival at the hospital were studied. There were 8 patients with respiratory acidosis, which were corrected after instituting airway management and mechanical ventilation. Most patients had normal sodium levels, except for the child who had fits. He had mild hyponatremia (serum sodium = 131) and he had been immersed in fresh water. No serum potassium abnormalities were found. Haematocrit and serum haemoglobin levels were within normal limits for the respective sexes, except for 1 lady with anaemia who had been rescued from a swimming-pool. From the MCV and MCHC, we found that she had a microcytic, hypochromic type of anaemia, suggestive of pre-existing anaemia (either thalassaemia or iron deficiency anaemia). It was unlikely to be due from haemolytic or dilutional anaemia associated with fresh-water drowning, as this will be of the normocytic, normochromic type. However, no further investigations were done on her to determine the exact cause of the anaemia.

Eleven of the 15 survivors had pulmonary oedema on their initial chest X-rays, and 6 needed intubation and ventilatory support. Five were extubated within 2 days; the last was in a vegetative state and needed long-term ventilatory support. Six of the 11 patients with pulmonary oedema went on to develop superadded chest infections (3 of them were in the intubated group, the remaining 3 were not). All the episodes of chest infection responded to antibiotics. We were unable to isolate any organism successfully from these patients.

Other complications such as renal failure, disseminated intravascular coagulation, and adult respiratory distress syndrome were not encountered.

Discussion

Submersion injuries are not common causes of environmental injury in Singapore compared to heat injury, or animal bites and stings. The A&E medical officer may not have as much experience with this entity. Nevertheless, a knowledge of its pathology and management is essential.

The most serious immediate pathophysiologic consequence of near-drowning is hypoxaemia,[1] which usually is due to aspiration-induced non-cardiogenic oedema (or acute respiratory distress syndrome, ARDS). This is because inhalation of water results in vagally-mediated pulmonary vasoconstriction and pulmonary hypertension. In addition, both fresh and salt-water aspirations produce diffuse alveolar capillary membrane damage. Therefore, initial resuscitative efforts need to be directed at establishing adequate oxygenation and ventilation. Mechanical ventilation, with the judicious use of positive end-expiratory pressure, clearing the airway of regurgitated fluid and debris is of prime importance. Intravenous diuretics are of no help in this situation, as the problem is not one of fluid overload.

It is also known that following an apparent period of recovery, a survivor may still develop delayed symptoms and signs of non-cardiogenic pulmonary oedema as late as 24 hours after the initial insult. This is commonly referred to as secondary drowning.[1] The phenomenon is thought to be due to loss of surfactant from

TABLE IV: INITIAL LABORATORY RESULTS OF THE PATIENTS WHO SURVIVED

S/N	Type of drowning	Art blood gases	Sodium levels (mEq/l)	Potassium levels (mEq/l)	Haemoglobin (g/dl)	Haematocrit
1	Pool	Normal (pH = 7.4)	135	4.1	12.9	39.70%
2	Pool	Normal (pH = 7.35)	139	4.3	12.6	42.40%
3	Pool	Normal (pH = 7.4)	136	4.2	12.0 (low)"	35.3% (low)
4	Pool	Normal (pH = 7.4)	137	3.7	14.1	40.00%
5	Pool	Normal (pH = 7.39)	135	3.7	14.3	4 1.40%
6	Pool	Resp acidosis (pH = 7.2)	13 1 (low)	3.7	13	39.70%
7	Pool	Resp acidosis (pH = 7.0)	141	4.4	12.3	43.40%
8	Pool	Resp acidosis (pH = 7.3)	135	3.5	15.2	45.30%
9	Pool	Resp acidosis (pH = 7.1)	138	4.5	14.1	39.60%
10	Pool	Resp acidosis (pH = 6.6)	133	3.7	13.3	40.00%
11	Sea	Normal (pH = 7.4)	143	3.9	13.5	41.30%
12	Sea	Normal (pH = 7.38)	138	4	14.9	40.00%
13	Sea	Resp acidosis (pH = 7.2)	144	4	15.3	42.70%
14	Sea	Resp acidosis (pH = 7.30)	142	4.7	15.6	45.60%
15	Sea	Resp acidosis (pH = 7.2)	145	4.6	15.8	50.10%

* Microcytic, hypochromic anaemia suggesting pre-existing anaemia

chemical, osmotic and anoxic damage to the alveolar cells.[2] For this reason, it has been our unit's policy to admit all near-drowning victims for observation for at least 24 hours. Recently, however, there have been recommendations that completely asymptomatic patients with normal vital signs, oxygenation and chest radiographs require only 4 to 6 hours of observation." We note that 4 of the 15 survivors in our series had normal chest X-rays initially, and they were discharged within 2 days, with uneventful recoveries. Perhaps this recommendation can be adopted as a future guideline.

Many of the reported series in the literature note that young children under 12 form the majority of victims.[3-5] There is another smaller peak consisting of victims who are young men in the 20 to 29 age group.[6,7] The reason for drowning in the first group is usually due to a lack of adult supervision, while the main reason for drowning in young men is due to risk-taking behaviour in aquatic sports. We note that in our series, the majority are men over the age of 15.

There has always been an attempt to distinguish between fresh and salt-water drowning by our doctors. It is believed that in the former, the entry of hypo-osmolar fluid into the blood stream will cause hyponatremia and resulting expansion of blood volume and haemolysis, while in the latter, a rise in serum electrolytes and a reduction in circulating volume will occur. However, the work of Modell[8] has challenged these theoretical considerations. In order for fluid and electrolyte abnormalities to arise, victims will have to aspirate more than 22 ml of fluid per kilogram body weight. Only 15% of those who die in water aspirate more than this quantity in post-mortem studies. This seem to be borne out in our series, where only 1 out of the 15 survivors had electrolyte changes, with mild hyponatremia (131 mEq/l) following immersion in the pool. Perhaps the emphasis should be shifted to the identification of the source of water, as aspiration of water from lakes, rivers and drains would be more likely to result in pneumonia in view of the greater bacteria load, than that from sea water.

Excluding associated injuries and other more occult causes of drowning should be foremost on the A&E doctor's mind, after the airway is secured and ventilation established. Most authors would agree that cervical spine injury should be excluded[1,9] in a patient with an impaired sensorium. We have found other unexpected causes such as suicide, drug overdose, fits and alcohol intoxication. The A&E doctor should have a high index of suspicion for other conditions as listed in Table V.

The commonest complication in our study was chest infection following aspiration of water in 6 patients (3 after aspirating sea-water, and 3 after aspirating fresh-water). We were unable to culture any organisms from sputum studies. They resolved uneventfully after antibiotics were given.

TABLE V: CONDITIONS ASSOCIATED WITH DROWNING AND NEAR-DROWNING

Causes of drowning
* Young age
* Extreme fatigue
* Venomous stings by aquatic animals
* Suicide
* Alcohol or drug intoxication
* Hypoglycaemia
* Epilepsy
* Acute myocardial infarction
* Cerebrovascular accident
* Post-hyperventilation
* Cerebral air embolism
* Non accidental drowning
* Decompression sickness in deep water diving
* Intentional hyperventilation
Associated injuries
* Hypothermia
* Cervical spine injury and other trauma
* Head or other injuries

There are some factors that have been studied in the literature and used to predict neurologic outcomes for victims of near-drowning. Hypothermia is well-recognized as being protective for the brain[10] invictims of cold water drowning. This does not apply in Singapore. Habib and colleagues[11] studied 93 victims of warm water drowning, and found that no child (n = 21) arriving comatose and asystolic in the Emergency Department survived neurologically intact (either died or became vegetative). On the other hand, 72 patients who presented to the A&E department with a detectable pulse and blood pressure recovered to their pre-submersion status, regardless of their neurologic status then. Kyriacou et al[12] also found that immediate or very early CPR played a big role in determining neurologic outcome. They studied 166 children, and found that children with a good outcome were 4.75 times more likely to have a history of immediate resuscitation than children with poor outcomes. Lastly, Graf et al[13] studied 194 children and found that among comatose children, unfavourable outcome was associated with an absent pupillary light reflex, increased initial blood glucose concentration, and male sex. Although these studies were from data collected in children, it seems applicable to adults too, as all our adult patients who received early CPR, and who had intact pulses, pupillary reflexes and good conscious levels upon arrival at the A&E department, survived neurologically intact.

What newer treatment modalities are there for the lung injury following aspiration of fluid? One recent case report from Austria[14] reported on the use of exogenous surfactant and high frequency oscillatory ventila-

tion for a 3-year-old boy following the onset of ARDS secondary to near-drowning. The child recovered favourably.

Prevention is of utmost importance. More than half of our victims sustained submersion injury while in swimming pools. Those that were in public swimming pools were immediately attended to by life-guards, and the provision of CPR saved at least 6 lives. However, there were no life-guards in attendance at the swimming pools in housing estates. A similar situation also occurred in Harris County, Texas. Warneke and Cooper[15] studied childhood and adolescent drownings in that area from 1983 through 1990. The majority of their 196 unintentional drownings occurred in swimming pools. Half of the pool drownings occurred in apartment pools and 33% in private home pools. It is neither logical nor financially feasible to employ a full-time life-guard for small private pools. A better alternative would be to ensure better safety design. A pool that is fenced off at its perimeters, with a self-latching gate will at least prevent the unsupervised entrance of young toddlers into water. Life-buoys and long poles with nets should be placed at the poolside. This was the measure proposed and introduced by legislation in New South Wales in 1994.[16] Such measures will help reduce the access of young children to pools.

Conclusion

Drowning and near-drowning accidents are relatively rare causes of environmental injury in Singapore. A doctor working in the A&E department will most likely encounter only 1 case in a 6-month posting. While the problem is mainly one of respiratory support, with the need for intubation and mechanical ventilation being prime considerations, the A&E doctor must not forget to look for unusual causes of drowning, as well as any associated occult injury of the head and neck, no matter how unlikely. In a drowning patient with abnormal sensorium, cervical spine immobilization should be instituted until the neck is cleared clinically and radiologically. Associated drug overdose and alcohol intoxication may also have to be excluded.

There is little to be gained by distinguishing between fresh and salt-water drowning. Outmoded treatment modalities such as diuretic therapy should be abandoned. More importantly, attention should be paid to airway management and adequate ventilation and oxygenation.

Predictors of good outcome include good pupil reactivity, presence of palpable pulses, early CPR and a good conscious level upon presentation at the A&E department.

Prevention is of utmost importance. Bystander CPR given by trained life-guards play a significant role in saving patients. We should consider the possibility of having life-guards in attendance at seaside beaches on a regular basis, as is the case at our public swimming pools. For smaller pools such as those in private condominiums, legislation can also play a role in ensuring that safety features such as life-buoys, fenced barriers and latched gates are incorporated in their design.

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