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REVIEW

Drowning

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Abstract

A body recovered from the water does not necessarily imply that death was due to drowning. The diagnosis of drowning is discussed together with the significance of the "diatom" and biochemical tests.

Key words: Cadaveric spasm, "Champignon de mousse", drowning, diatoms, fresh water, sea water.

INTRODUCTION

Drowning is the result of immersion, partial or complete, in a fluid medium. The medium is usually water but James[1] reported a case of drowning in a vat of beer. The death rate of drowning has been estimated in the U.S.A. as 2.5 per 100,000 population.[2]

With the increase in popularity of boating and water sports, a larger population is at risk. Although complete immersion is usual, drowning may occur when the nostrils and mouth only are covered by fluid. In cases where immersion is "partial", a predisposing factor must be considered (e.g. loss of consciousness due to head injury, an epileptiform attack, myocardial infarction or alcoholic intoxication).

CLASSIFICATION OF DROWNING

This state can be morphologically classified into (a) dry (atypical) drowning, (b) wet drowning, and (c) secondary drowning."

In "wet" drowning the classical features of drowning are evident, whilst in "dry" or atypical drowning, there are little or none of the features associated with typical drowning. In such cases, death is attributed to either vagal stimulation (cardiac inhibition) or laryngeal spasm due to submersion. In secondary drowning, the victim is recovered from water alive but succumbs from about an hour to several weeks later. This type is usually associated with metabolic acidosis, pulmonary oedema or chemical pneumonitis.

In cases where the body has been recovered from water, especially cold water, the possibility of suspended animation must be considered and resuscitation procedures continued for some time before life is pronounced extinct.

GENERAL OBSERVATION

A. External features

Hypostusis

Post mortem hypostasis may be confined to the head, neck and front of the chest. This distribution is because a fully submerged body tends to float with the face downwards and the buttocks upwards. Movement of the body in water will influence the development of hypotasis and thus may not be obvious in these circumstances. The hypostasis may have a pink tinge suggesting carbon monoxide poisoning but distinguishable from it by its distribution and the absence of carbon monoxide in the blood. The colour is due to exposure and oxygenation of the dependent blood and its distribution is determined by the position of the body as it floats in the water.

Cutis anserina

Goose-flesh (cutis anserina) may be present. It can occur between somatic and molecular death and is found in bodies recovered from water and also in circumstances other than drowning and hence is of no diagnostic significance.

Washer-woman hands

Sodden, wrinkled hands and feet – "Washerwomen's hands" (Fig. 1) occur as a result of submersion in water, irrespective of whether the body was immersed before or after death. The earliest skin changes - whitening and

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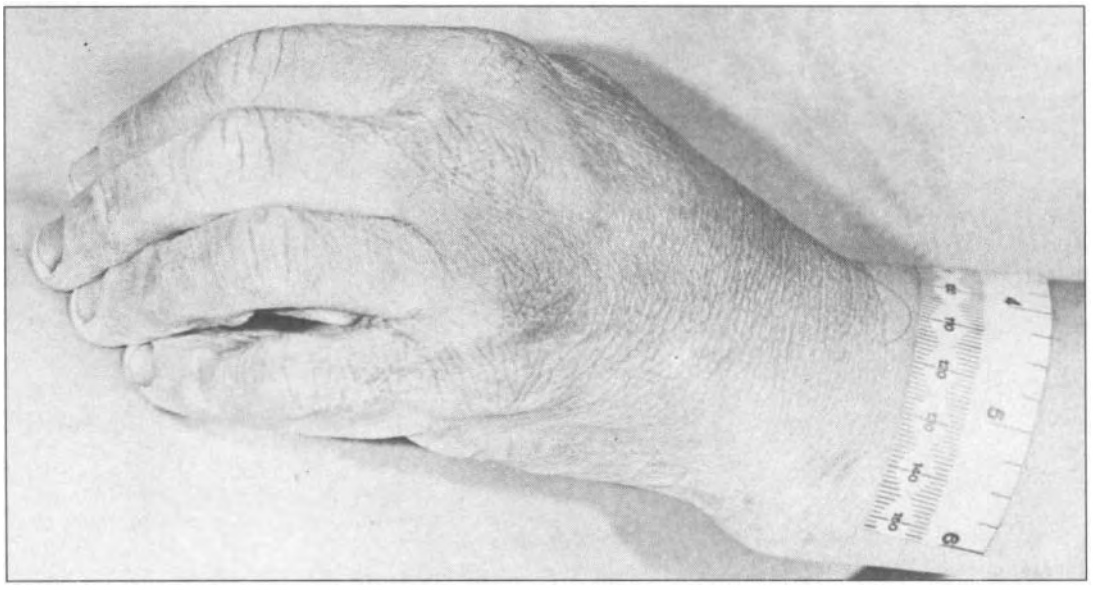

FIG. 1: Hand showing "washer-woman" effect.

wrinkling - appear on the back of the hands in about 5-8 hours in summer, and 3-5 days in winter." As the duration of immersion in water increases, by the end of the first week early signs of separation of the skin of the pulps of fingers and toes occur with complete separation including the nails occurring in about 3-4 weeks. These changes may be delayed during the winter months and hastened during the summer period. These changes in the feet will be delayed if the deceased wears shoes.

"Champignon de mousse"

The presence of foam at the mouth and nostrils is an important sign of drowning. particularly if the body is freshly recovered from water and has not undergone putrefaction and other causes of pulmonary oedema can be excluded (Fig. 2). Other causes of pulmonary oedema are epileptic fits, acute left ventricular failure and toxic fumes.

This foam is "fine froth", white or pink in colour and, when wiped away, more may appear. Even if not evident externally, it can be seen in the upper air passages. The production of tenacious foam in drowning is essentially a vital phenomenon. The entry of fluid into the air passages provokes them to produce mucus. This substance when mixed with water and possibly surfactant from the lungs is readily whipped into a tenacious foam by the violent respiratory efforts of the victim." Froth may also appear around the mouth and nostrils in advanced states of putrefaction. Under these circumstances the

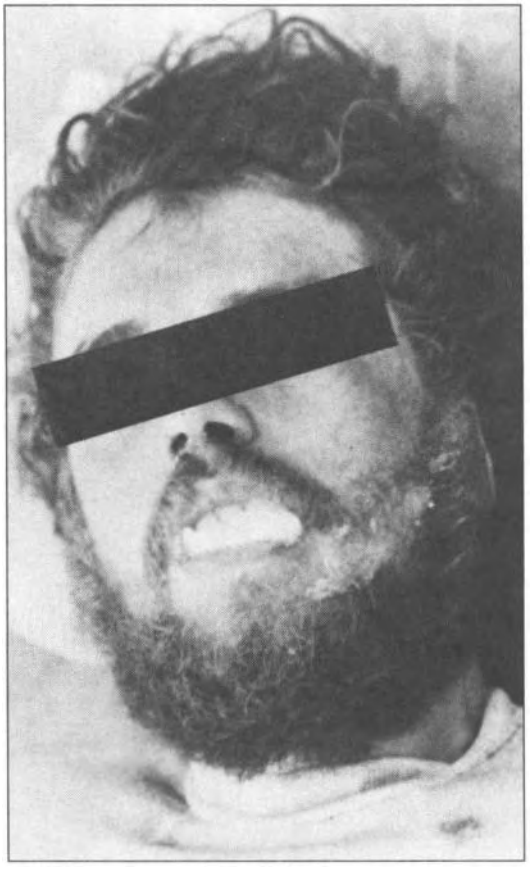

FIG. 2: "Champignon de mousse" in a recently recovered body from a river.

foam is of a coarse appearance and blood stained. The interpretation of such "froth" must be guarded and no firm conclusions can be drawn from it.

Cadaveric spasm

This uncommon event, if present, with weeds or other material from the river bed or bank firmly grasped in the hand, provides valuable evidence of life at the time of submersion.

Nail scrapings

This is a practice not routinely carried out, but if sand, mud or other material similar to that present at the 'scene' were found, this would suggest contact with it either before or after death.

Injuries

Injuries may be the result of an incident prior to entry into water or during or after submersion. Injuries sustained after submersion can be the result of being attacked by fish etc, or the result of contact with boats (propeller), etc. The presence or absence of vital reaction would be of assistance in differentiating these injuries but it must be remembered that head injuries sustained after death may bleed and resemble antemortem injuries.[4]

B. Internal features

The internal findings of drowning are obscured or abolished if putrefactive changes are advanced.

The brain, liver, kidney and pancreas show no specific features.

Most of the significant findings are in the respiratory system with some non-specific changes in the cardio-vascular system. The air passages may contain fine foam (already mentioned) and a variable quantity of water. The larynx may be congested.[5] The pleurae may show haemorrhages but not the pinpoint petechial haemorrhages of the asphyxial type, which are infrequent[4]. These haemorrhages may be due to tearing of the interalveolar partitions[6]

The lungs are bulky and ballooned and tend to overlap the pericardium. Rib markings may also be present. The lung weight is increased and on sectioning, watery fluid exudes, which can be blood stained. The state of the lungs in drowning has been described as "emphysema aquosum". The degree of emphysema aquosum will depend on the time taken to drown, being absent if unconsciousness or death resulted from cardiac inhibition.

The mechanism of production of emphysema aquosum is related to the production of fine foam (already discussed). When sufficient foam has been produced, it acts like a check valve when powerful inspiratory efforts carry the air past the obstructions but the expiratory efforts are insufficient to expel the air, water and foam.

In the heart, the right ventricle and atria may be dilated and the great veins distended with fluid blood. The aorta (in a "fresh" body) may show haemolytic staining of the intima.

C. Dry (atypical drowning)

The incidence of this type of drowning is reported as 10-15% of cases.' When the classical features of "wet" drowning are not present and other causes of death have been excluded viz natural or deaths due to violence - death could be attributed to dry drowning, the mechanism being either due to vagal stimulation resulting in cardiac inhibition or laryngeal spasm.

Vagal stimulation

The sudden inrush of water into the nasopharynx or larynx may be responsible for this phenomenon. Gardiner[8] and Spilsbury[9] have reported such deaths. Surprise or the extreme coldness of the water may play an important role in the causation of this reflex effect.

Laryngeal spasm

It is likely that in deaths due to drowning, varying degrees of laryngeal spasm occurs. In such instances, the spasm is a transient or intermittent factor. In those circumstances when death is attributable solely to laryngeal spasm the features of mechanical asphyxia will be evident. The lungs are not waterlogged with little or no fluid in the air passages. Since dry drowning is a rare mode of death from submersion, care must be taken to exclude mechanical causes of asphyxia when asphyxial signs are prominent. Modell[10] suggested that 10% of drowning victims die of asphyxia due to laryngospasm.

TIME TAKEN TO DROWN

The time taken to drown varies widely depending on a number of factors: the nervous state, physique, reaction to submersion, ability/inability to swim, temperature of the water, the volume of water inhaled and the consistency of the water (salt/fresh); death being almost immediate when

due to cardiac inhibition, and more rapid in fresh water than in sea water. It is also rapid in those who are unable to swim, with poor physique and when submersion is unexpected.

MECHANISM OF DROWNING

(i) Fresh water

The inhalation of water results in its absorption by the circulating blood. This can occur within a few minutes following total submersion with coincident haemolysis. The heart muscle sustains "serious biochemical insult,"" there being an increase in plasma potassium with sodium loss. The haemodilution also overloads the circulation. This, along with myocardial anoxia, is responsible for a fall in the systolic blood pressure and fibrillation.

(ii) Sea water

Unlike fresh water drowning where there is haemodilution, in salt water drowning there is haemoconcentration. There is withdrawal of water from the circulating blood into the lungs whereby massive pulmonary oedema occurs. Electrolyte exchange from sea water into the blood occurs with an increase of plasma sodium levels. Ventricular fibrillation is not a feature but, with the occurrence of myocardial anoxia and increased blood viscosity, rapid failure of the heart occurs.

SECONDARY DROWNING (NEAR DROWNING)

Persons who survive the initial episode of submersion may subsequently suffer complications or even die after a period apparent of wellbeing.'.'?

The clinical symptoms and signs include pyrexia, shallow respiration, blood stained frothy sputum and pain in the chest with cardiac arrythmias. Electrolyte changes are not significant. Coma precedes death. If active treatment is instituted, the prognosis is good in cases of fresh water submersion but poor in salt water immersion.

AQUATIC SPORT AND DROWNING

Fatalities associated wtih aquatic sport are usually directly attibutable to drowning rather than hyperbaric effects. In the case of the sub-aqua diver, the acute problem is one of decompression, but the skin diver who deliberately overbreathes to wash out CO, and thereby increase his breath holding time runs the risk of losing consciousness and drowning follows quickly.

At the end of such effort the arterial pO_2 is low but his deliberately reduced pCO_2 delays the onset of respiratory efforts. Peripheral pooling of blood occurs when exertion ceases and cardiac output falls resulting in cerebral hypoxia, this accounting for the loss of consciousness and death by drowning.

Water-skiing accidents can also lead to death by drowning, particularly if a severe head, or skeletal or organ injury is sustained."

DIATOMS AND DROWNING

Diatoms are microscopic unicellular or colonial algae with distinctive cell walls impregnated with silica and containing chlorophyll pigment. They are universally distributed in fresh and salt water and comprise over ten thousand species ranging in size from a few to several hundred micra in diameter.

The "diatom test" is based on the principle that diatom species measuring up to 30 micra in diameter are said to be able to enter the pulmonary circulation during immersion and are disseminated widely to sites like liver, brain, kidney and marrow.

Method for demonstrating diatoms

Several grams of the organ suspected of harbouring the diatoms (liver, kidney or bone marrow) are digested with fuming nitric acid until all organic material has been destroyed and heating is continued until only a small volume of fluid remains. The solution is centrifuged and the supernatant decanted and discarded.

The residue is washed several times in distilled water. After final centrifugation and disposal of the wash water, the residue is poured on a clean slide, covered with a cover slip and examined under the microscope with subdued light. The diatom skeletons are readily recognizable as radially or axially symmetrical structures. There are other methods available for the demonstration of diatoms:[6]

a. *Direct microscopic examination*: done only in the examination of the lungs. Water is squeezed from the lungs and centrifuged and the sediment is examined.

b. *Incineration method*: the organic matter (brain, liver etc.) is destroyed with heat in an oven. The principle is that diatoms are heat resistant.

Interpretation of the diatom test

The demonstration of diatoms from the submerging fluid in the body of the victim is of value as a confirmatory test of death by drowning. Examinations of lung juices have limited value, although a high diatom content is indicative of drowning. Timperman[14] found that after death diatoms penetrate only as far as the main bronchi. Tamaska[15] regards the identification of diatoms in the bone marrow as the best method in all circumstances of drowning, including those where the body is in an advanced state of putrefaction. This view has been confirmed by Rushton[16] who, because of the difficulty of total exclusion of contamination, considered the finding of diatoms as supportive evidence but not as conclusive evidence. W. V. Spitz, at the Third International Meeting in Forensic Medicine, London in 1963 showed that diatoms were plentiful in the air of Berlin.[17]

Peabody[18] has therefore suggested the need for further research to resolve the controversy by establishing with certainty whether non-drowned subjects do have diatoms in their organs in significant number, and to what extent results may be vitiated by contamination of reagents and glassware.

EXPERIMENTAL EVIDENCE

Experiments of Swan and Spafford[19] produced results on which the modem view of drowning is based.

a. Fresh water

When dogs were submerged in fresh water, large amounts of water were rapidly absorbed. Within three minutes the circulating blood could be diluted by as much as 72% with coincident haemolysis. The heart muscle thus sustained a "biochemical insult". There was an increase in plasma potassium with a fall in sodium. In addition, there was myocardial anoxia. Haemodilution also overloaded the circulation. A rapid and considerable fall in systolic blood pressure occurred and within a few minutes, ventricular fibrillation occurred causing cerebral anoxia and death.

b. Sea water

In sea water the mechanism is different. Swan and Spafford showed that in sea water there is haemoconcentration; up to 42% withdrawal of water from the circulating blood into the lungs, causing massive pulmonary oedema. Exchange of electrolytes from sea water to the blood also has its adverse effects. The haematocrit and plasma sodium levels rise steeply.

Ventricular fibrillation is not a feature of sea water drowning, and heart failure is slower, taking from 5-8 minutes. The cause of death is myocardial anoxia and the increased viscosity of the blood causes heart failure. There is no haemolysis.

Modell[10] reviewed the mechanism of drowning. He suggested that 10% of drowning victims do not aspirate water but die of asphyxia due to laryngospasm. He also demonstrated that when fresh water was aspirated there was a decrease in serum sodium, chloride and calcium, with an increase of potassium in arterial blood. Fresh water drowning was considered to be twice as lethal as sea water drowning.

CHEMICAL TESTS OF DROWNING

Gettler[20] and Fisher[21] were of the opinion that comparison between the chloride content of blood samples taken respectively from the right and left sides of the heart would furnish a test of death by drowning. This was on the principle that in fresh water drowning, the blood in the left side of the heart, being diluted by water, should have a lower chloride content than that in the right, and conversely if drowning occurred in salt water. Timperman[14] and Modell and Davis[22] considered these tests untrustworthy. Rammer and Gerdin[23] compared the osmolarity and serum sodium and potassium in the left and right sides of the heart with that in the cerebro-spinal fluid and were of the opinion that a lower osmolarity and a substantially lower concentration of sodium and potassium than that found in the cerebro-spinal fluid made a diagnosis of drowning in fresh water highly probable.

For these biochemical tests to be of value as evidence of drowning, samples must be obtained within a few hours of submersion.

Post mortem biochemistry, particularly of the vitreous and cerebro-spinal fluid may not only be indicative of sea water drowning, but also provide a means of determining how long a dead body may have been in sea water. Coutseliuis[24] demonstrated a progressive increase in magnesium in the vitreous of exenterated human eyeballs put in sea water and was of the opinion that this provides a means of determining how long a dead body may have been in the sea. The concentration of magnesium in the cerebro-spinal fluid helps in establishing the diagnosis of drowning in sea water whilst

magnesium concentration determinations from the right and left side of the heart pose problems similar to chloride concentration estimations.

Estimation of serum strontium levels in rabbits before and after death by Abdallah ***et al.***[25] concluded that serum strontium levels were a practical measure for differentiating between death due to drowning, and post mortem immersion of a victim. They showed that death by drowning raises the serum strontium levels of the cadavers, and this was more marked in cases of sea water drowning than in fresh water drowning.

ACCIDENT - SUICIDE - HOMICIDE

Drowning may be accidental, suicidal or homicidal. The vast majority are accidental[26] whilst 10% to 30%[6,26] are suicidal. Homicidal drowning is only occasionally reported and the victims are usually children. Circumstantial evidence is of value in assessing whether death was accidental - boating accidents, accidents whilst pot holing, or skiing on a lake covered with a layer of thin ice, can result in drowning. Accidental drownings have occurred in swimming pools, both in those in use and in disused ones.

Suicidal drowning can occur in similar locations, bath tubs, swimming pools, canals and the sea. When drowning is in shallow water and when there are no anatomical or toxicological reasons why the victims could not have saved himself or herself (viz. head injury, disabling natural disease or alcoholic intoxication) this cause needs serious consideration.

It is not unusual for a would-be suicide by drowning to weight himself or herself with rocks or heavy weight before entering the water. Similarly they may tie their hands and/or feet together before the fatal entry into the water. The nature and type of material and knot used will be of value in assessing the case.

Homicidal drowning may be committed by an act of omission or commission. The former is occasionally seen in cases of infanticide. The diagnosis of homicidal drowning of children may be made more difficult by the absence of any other injury. Adult victims of homicidal drowning on the other hand have injuries indicative of a fight - craniofacial trauma or even attempted strangulation or evidence of being made defenceless by alcohol and drugs.

Finally in the examination of any body recovered from water, particularly one where the entry has not been reliably witnessed, homicide by other means with subsequent post-mortem submersions to stimulate accidental or suicidal drowning must always be considered, before being excluded.

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