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Lecture Notes

Bodies from Water

SUMMARY

1. Immersion artefacts occur in any corpse immersed in water, irrespective of whether death was from drowning or the person was dead on entering the water. Therefore, immersion artefacts do not contribute to proof of death by drowning. However, such artefacts are typically the most striking findings in a body recovered from water.

These immersion artefacts include:

1. goose-skin, or anserina cutis, which is roughening, or pimpling of the skin,
2. skin maceration, or washer-woman's skin, which is swelling and wrinkling of the skin, and
3. adipocere, which is the transformation of the fatty layer beneath the skin into a soap-like material—a process requiring many weeks or months.

2. Corpses in water always lie with the face down and with the head hanging. Buffeting in the water commonly produces post-mortem head injuries, which may be difficult to distinguish from injuries sustained during life. The presence of bleeding usually distinguishes ante-mortem from post-mortem injuries. However, the head down position of a floating corpse causes passive congestion of the head with blood, so that post-mortem injuries tend to bleed, creating the diagnostic confusion.

3. The normal changes of decomposition of a body are delayed in cold, deep water so that bodies may be surprisingly well preserved after a long period of immersion. These conditions also favour the formation of adipocere (see 1 above) which protects against decomposition.

4. When a body is recovered from water, two critical questions require resolution: Was the victim alive or dead when he entered the water? Is the cause of death drowning? (and if not, what is the cause of death?).

5. To resolve the above questions, the following information must be correlated:

1. the circumstances preceding the death,
2. the circumstances of recovery of the body, and
3. the autopsy findings. The approach should be to consider the circumstances revealed by the investigation and to then determine if the autopsy findings are consistent with those circumstances.

6. Drowning is "suffocation due to immersion of the nostrils and mouth in a liquid". The

mechanism of death is complex and is not simply an asphyxiation due to suffocation.

7. Submersion is followed by struggle which subsides with exhaustion and drowning begins. When the breath can be held no longer, water is inhaled, with associated coughing and vomiting, and is rapidly followed by loss of consciousness with death some minutes later.

8. Instantaneous death may occur following sudden, unexpected immersion in cold water. This is "atypical drowning" due to vagal inhibition - a sudden stopping of the heart mediated by the nervous system.

9. Hypothermia (death from loss of body heat) may occur following immersion in water with a temperature less than 68^o F. A healthy person in ordinary clothes and wearing a lifejacket would have an expected survival time of less than three-quarters of an hour at temperatures less than 35^o F, less than 11/2 hours at 35-40oF, and less than 3 hours at $40–60^o$ F.

10. There are no autopsy findings pathonomonic of drowning. Consequently, obtaining proof that the victim was alive on entering the water, and excluding the presence of natural, traumatic and toxicological causes of death, are critically important. Some pathological changes are characteristic of drowning, but the diagnosis is largely one of exclusion.

11. A fine, white, froth or foam in the airways and exuding from the mouth and nostrils is characteristic of drowning. It is a vital phenomenon and indicates that the victim was alive at the time of submersion. However, similar foam is found in deaths from other causes, e.g. heart failure, drug overdose, and head injury.

12. The lungs are characteristically over-inflated and heavy with fluid. However, this is not invariable and, when present, is not distinguishable from "fluid on the lungs" (pulmonary oedema seen in heart failure, drug overdose and head injury).

13. It is disputed whether sand, silt, weed, and other foreign matter, found in the airways constitutes proof of immersion during life. The presence of large quantities of water and debris in the stomach strongly suggests immersion during life. Conversely, the absence of water in the stomach suggests either rapid death by drowning, or death prior to submersion.

14. Haemorrhages in the boney middle ears are occasionally (some would say commonly) seen in drowning cases. Such haemorrhages also occur in deaths from other causes, e.g. head trauma, electrocution and mechanical asphyxiation.

15. There are no universally acccepted diagnostic laboratory tests for drowning. The diatom test is used in some British laboratories and may provide corroborative evidence of death by drowning.

INVESTIGATION

These cases represent a challenge because:

1. The mechanism of death in drowning is neither simple nor uniform.
2. The circumstances of drowning introduce further variables.

The questions to be resolved by the investigation are:

1. Did death occur prior to or after entry into the water? (i.e. was the victim alive or dead at the time of entry into the water?)
2. Is the cause of death drowning? If not what is the cause of death?

3. Why did the victim enter the water?
4. Why was the victim unable to survive in the water?

To resolve these issues the following information must be correlated?

1. Circumstances preceding the death.
2. Circumstances of recovery of the body from water.
3. Autopsy and laboratory analyses.

A full investigation of the circumstances preceding the death requires the identification of the victim which therefore become a priority.

The correct interpretation of the autopsy findings and indeed the performance of some autopsy procedures is dependent upon a careful examination of the circumstances preceding death and of body recovery. The approach should be to consider the circumstances revealed by thorough police investigation and to then determine if the autopsy findings are consistent with those circumstances.

In those instances where the cause of death is drowning it is then necessary to answer the questions 3 and 4 above. The investigative scheme must encompass both environmental factors and human factors. "Human factors drowning" implies that human deficiencies were the significant factor in the drowning episode e.g. inexperience, poor judgement, intoxication.

(modified from Davis 1986)

Investigative Considerations - Case Example

An 80 year old male swimming in warm ocean water in mid-summer. He was found dead in the water and the body recovered. Autopsy disclosed minor degrees of pulmonary congestion and oedema. There was severe coronary artery atherosclerosis with posterior wall myocardial fibrosis but no evidence of recent infarction or coronary thrombosis.

Consider the environmental and human factors. Some alternatives are:

1. A fatal cardiac dysrhythmia with a collapse "dead" into the water.
2. A fatal cardiac dysrhythmia with collapse into the water and agonal aspiration of some water.
3. A non-fatal cardiac dysrhythmia with syncope and collapse into the water and drowning.
4. Stepping into or being swept into deep water and an inability to escape due to a lack of cardiac reserve or lack of cardiac rhythmn stability.
5. Stepping into or being swept into deep water, panicking and drowning while the heart continued to function normally until overcome by the terminal anoxia of drowning.

Given these alternatives the death certificate might read:

1. Atherosclerotic coronary artery disease

2. . Atherosclerotic coronary artery disease with a contributory effect of "agonal aspiration of water".
3. Atherosclerotic coronary artery disease with a contributory effect of drowning.
4. Drowning with a contributory effect of atherosclerotic coronary artery disease.
5. Drowning.

(modified from Davis 1986)

CIRCUMSTANCE AND MANNER OF DEATH

The world incidence of death by drowning is estimated at about 5.6 per 100,000 of population. Approximately 1,500 deaths from drowning occur in the UK each year; 25% occur in the sea and the rest in inland waters; the majority of victims are young adults and children; two-third are accidental and one-third are suicidal; homicide by drowning is rare.

Accidental drowning of toddlers may be in uncovered fish ponds, the bath and swimming pools. Accidental drowning in adults is commonly associated with alcohol consumption and males predominate.

In suicidal drowning some clothing may be left in a neat pile close to the water. The pockets may be filled with stones or weights may be tied to the body. The hands or the feet are sometimes tied together and an examination of the ligatures will show whether they could have been tied by the deceased. There may be concurrent use of other suicide methods such as drug overdose or slashing of the wrists; alternatively there may be a history or autopsy evidence of previous suicide attempts. Persons jumping from a bridge or cliff into water may suffer injuries from impact with rocks or the water itself. Impact with the water can produce severe fatal injuries such as fractures of the ribs, sternum and thoracic spine and lacerations of the heart and lungs.

Homicidal drowning is uncommon and requires either physical disparity between the assailant and the victim or a victim incapacitated by disease, drink or drugs, or taken by surprise. Disposal in water may be attempted where the victim has already been killed by other means. A victim of infanticide is sometimes disposed of in this way. Autopsy is directed towards establishing injuries inconsistent with accident in the absence of signs of drowning.

The investigation of a death in a domestic bath may be made more difficult by the lack of accurate information concerning the position of the body as found and the level of the water.

First it must be established whether the nose and mouth were truly under the water. Such drownings will only occur if unconsciousness is produced by disease (epilepsy, coronary artery atherosclerosis) or the consumption of alcohol and/or drugs or a head injury from a fall. Suicide in the bath is rare but well documented. Homicide in the bath is described (the "Brides in the Bath"). Intravenous drug abusers may place an individual who collapsed from an adverse reaction to a drug in a water-filled bath during attempted rescuscitation; drug paraphernalia are typically found nearby. Where the victim is a woman of child bearing age then pregnancy and abortion should be suspected. The domestic bathroom presents other hazards than drowning such as electrocution and carbon monoxide poisoning from faulty heaters.

Persons unconscious by reason of natural disease and injury can drown in quite shallow water so long as it is sufficiently deep to cover the nose and mouth.

Diving into shallow water may result in impact of the forehead against the bottom with resultant hyperextension of the head and loss of consciousness. Common autopsy findings are haemorrhage in the deep muscles of the neck with or without associated fracture of the cervical vertebrae. Bruises and abrasions on the face or forehead may provide evidence of the impact.

Individuals engaged in underwater swimming competions may hyperventilate prior to entering the water. This can result in sudden loss of consciousness and drowning. The postulated mechanism is that overbreathing so reduces the carbon dioxide content of the blood that there is no activation of the repiratory centre even when the arterial oxygen tension falls to a critical level and consciousness is lost.

In skin diving a mask and fins are used and it is essentially an extension of swimming with similar hazards. SCUBA is an acronym for self contained underwater breathing apparatus. This apparatus allows the diver to reach depths not usually attained by skin divers. The hazards are those of drowning and baro-trauma. The commenest problems include "the bends" (caisson disease, decompression sickness), acute pulmonary emphysema, pneumothorac and systemic air embolism. The latter three are stages of the same process resulting from excessive pressure in the lungs ("extra-alveolar air syndrome"). Investigation of these deaths requires examination of the scuba apparatus by an expert as well as specialist advice as to the circumstances.

Prolonged immersion in water less than 68^oF carries the threat of hypothermia. For a person in good health ordinarily clothed and wearing a life jacket, the expected survival time for given water temperatures are: less than 3/4 hour at less than 35^o F; less than 11/2 hours at 35-40^o F; less than 3 hours at 40-50^o F; less than 6 hours at 50-60^o F.

DROWNING

Definition:—suffocation due to immersion of the nostrils and mouth in a liquid.

Qualifications:

the mechanism of death is complex and varies somewhat with circumstances. It is not simply an asphyxiation due to suffocation in a liquid.

immersion of the nostrils and mouth is the minimal requirement, typically the entire body is submerged in the liquid.

the liquid is most commonly water but drowning can occur in any liquid e.g. beer, wine, gasoline, bitumen, dye, paint or some other chemical solution.

Mechanism of Death

Drowning was originally conceived as suffocation due to the mechanical obstruction of the airways by liquid. The animal experiments of Swann and his colleagues during 1947-51 highlighted the pathophysiological importance of disturbances of blood electrolytes and fluid balance. In the experiments dogs were completely submerged in salt water and fresh water.

In fresh water and brackish water (approximately 0.5% salinity) drowning the aspirated water is rapidly absorbed from the alveoli into the circulation producing an expansion of blood volume, haemodilution and haemolysis. Within three minutes of submersion haemodilution was up to 72%. Circulatory overload, hyponatraemia and sodium/potassium imbalance together with myocardial hypoxia resulted in a dramatic collapse of systolic pressure quickly followed in the majority of cases by ventricular fibrillation.

In salt water (3-4% salinity) drowning the aspiration of water results in withdrawal of water from the pulmonary circulation into the alveolar spaces as a result of the osmotic differential while at the same time electrolytes (sodium, chloride, magnesium) pass into the blood. There is haemo-concentration but not haemolysis and little change in the sodium/potassium balance. The pulse pressure decreases slowly and is followed by A-V dissociation but not ventricular fibrillation. Up to 42% of the water content of the circulating blood was absorbed into the alveoli.

In both fresh water and salt water drowning there is terminal pulmonary oedema. In both drowning media there is concurrent transfer of water in both directions between the alveolar spaces and the blood i.e. pulmonary oedema develops simultanteously with the diffusion process.

These experiments have been extrapolated to man but have been criticised because (a) the animals were always completely submerged and (b) the main intracellular cation in the dog erythrocyte is not potassium but sodium. The biochemical findings in humans surviving drowning are less distinct.

Phases of Drowning

1. Submersion is followed by struggle which subsides with exhaustion and drowning begins.

2. Breath holding lasts until carbon dioxide accumulation stimulates respiration resulting in inhalation of water.

3. Gulping of water coughing and vomiting is rapidly followed by loss of consciousness.

4. Profound unconsciousness and convulsions are associated with involuntary repiratory movements and the aspiration of water. Respiratory failure precedes heart failure in onethird of cases it is coincident in one-third and follows it in the other third.

5. Death occurs within 2 to 3 minutes (see below for "Instantaneous Deaths"). Death is almost invariable when the period of submersion exceeds 10 minutes. The survival rate from potentially fatal salt water submersion is about 80% whereas in fresh water it is less than 50%.

TYPICAL PATHOLOGICAL FINDINGS

There are no pathological findings pathognomonic of drowning. Consequently obtaining proof that the victim was alive on entering the water and excluding natural, traumatic and toxicological causes of death are critically important. Some pathological changes are characteristic of drowning but the diagnosis is largely one of exclusion.

1. Foam in the airways

Externally a fine white froth or foam is seen exuding from the mouth and nostrils. The froth is sometimes tinged with blood producing a pinkish colour. If the foam is wiped away then pressure on the chest wall will cause more to exude from the nostrils and mouth. It is persistent and resists submersion for several days (up to a week in winter). The foam is also found in the trachea and main bronchi.
The foam is a mixture of water, air, mucus and possibly surfactant whipped up by respiratory efforts. Thus it is a vital phenomenon and indicates that the victim was alive at the time of submersion. A similar foam is found with severe pulmonary oedema from any cause such as drug overdose, congestive cardiac failure and head injuries.

2. Emphysema aquosum ("emphyseme hydroaerique")

The lungs are voluminous/bulky/ballooned. The pleural surface has a marbled appearance with grey-blue to dark red areas interspersed with pink and yellowgrey zones of more aerated tissue. They feel doughy and pit on pressure. On sectioning there is a flow of watery material. The appearances reflect active inspiration of air and water and cannot be reproduced by the passive flooding of the lungs with water. However the appearances are not generally distinguishable from pulmonary oedema.

Contrary to expectations (see Mechanisms of Drowning) lung weights in fresh water drowning are not statistically different from lung weights in salt water drowning. The average lung weight is approximately 700gm with a standard deviation of approximately 200gm so that in a minority of cases the lungs are "dry".

Subpleural petechiae are rare but larger ecchymoses are sometimes seen most often in the interlobar surfaces of the lower lobes. Subpleural bullae which may be haemorrhagic are occasionally found. Haemorrhages are the result of tears in the alveolar walls and this is the explanation for the occasional blood tinging of foam in the airways.

For detailed histological studies one central and one peripheral section from each lobe is recommended. The tissue should be cut with a sharp knife avoiding squeezing out of the fluid content.

The microscopic appearance varies from being suggestive of drowning to entirely normal. Aspiration of large quantities of water results in overdistension of the pulmonary alveoli (emphysema aquosum) the alveolar septae are thinned and stretched with narrowing and compression of the capillaries. The appearances resemble pulmonary emphysema. The intensity of the changes reflects the circumstances of the drowning and are most pronounced in persons who drown over a relatively long period of time coming to the surface several times to inhale air.

3. Foreign material in airways, lungs and stomach

Sand, silt, weed or other foreign matter may be found in the airways, lungs, stomach and duodenum of bodies recovered from water. Disputed is whether the presence of such material consistitutes proof of immersion during life. When a victim is dead at the time of submersion, water and contaminating debris may enter the pharynx, trachea and larger airways; small quantities may enter the oesophagus and stomach. However water will not reach the terminal bronchioles and alveoli to any significant extent so that the finding of abundant foreign material generally distributed within the alveoli provides strong evidence of immersion during life so long as the body is recovered early (within 24 hours) from shallow water (less than 3 metres deep). Similarly the presence of large quantities of water and contaminating debris in the stomach strongly suggests immersion during life (there may be associated water blanching of the gastric mucosa). Conversely the absence of liquid in the stomach suggests either rapid death by drowning or death prior to submersion.

Debris and chemical contaminants present in liquid recovered from the lungs and stomach can be compared with samples of water from the place of submersion to provide corroboration that drowning occurred at that locale. Microscopy as well as chemical analysis of the gastric contents may be useful in this regard.

Vomitus may be found in the oesophagus and airways as a result of agonal inhalation or attempted rescuscitation. The presence of large quantities of sand in the upper airways raises the possibility of inhalation of a thick suspension of sand in seawater produced by heavy surf; death is very rapid in such cases.

4. Middle ear and mastoid air cell haemorrhage.

These are occasionally seen in bodies recovered from water and produce a bluepurple discolouration of the bone of the roof of the mastoid air cells. Their pathogenesis is unknown and their presence does not contribute to proof of death by drowning. They may be the result of baro-trauma or the irritant/pressure effects of aspiration of fluid into the eustachian tubes or extreme congestion. Such haemorrhages also occur in cases of head trauma, electrocution and mechanical asphyxiation.

5. Conjunctival haemorrhages

Occasional small conjunctival haemorrhages may be seen but the multiple petechial haemorrhages found in other asphyxial deaths are not seen in drowning (except in rare instances of rapid death associated with glottic spasm - see below). The conjunctivae are often congested.

6. Venous congestion and fluid blood

Heart failure combined with blood volume expansion from the absorption of fresh water are reflected in engorgement of the right side of the heart and large veins. As a result of haemodilution the blood is fluid and thin lacking its normal sticky consistency.

7. Foreign material in the hands

Victims struggling in water may clutch at objects which are then found grasped in the hand after death. Weeds, branches and other objects fixed in the hand by cadaveric spasm (instantaneous rigor) provides good evidence that the victim was alive and conscious at the time of submersion. Similar materials may be recovered from beneath the fingernails. Injuries to the hands or fingertips and tearing of the fingernails may be produced during attempts to grasp at objects.

8. Shoulder-girdle bruises

Victims struggling violently to survive in water bruise or rupture muscles particularly those of the shoulder girdle, neck and chest (most often the scaleni and pectoralis major). Haemorrhages may be bilateral and tend to follow the lines of the muscle bundles. They may be present in up to 10% of cases and are strong indicators that the victim was alive in the water. In decomposing bodies these haemorrhages should be examined histologically. Uneven putrefaction can cause reddish patches to develop in muscle through haemoglibin inhibition and this may be confused with haemorrhage. Extravascular erythrocytes provides histological proof of the existence of true haemorrhage.

ATYPICAL DROWNING

1. Vagal inhibition (cardiac arrest, laryngeal shock)

This is uncommon but well recognised. Loss of consciousness is usually instantaneous and death ensues soon afterwards, at most within a few minutes. Autopsy discloses none of the usual signs of drowning. The mechanism is believed to be cardiac arrest induced by impact of cold water on the back of the pharynx and larynx. The three circumstances common to these deaths are (a) entering the water feet first, (b) surprise or unpreparedness and (c) a "state of hypersensitivity" e.g. alcohol intoxication. Entering the water feet first it is easy for liquid to pass up the nose. Alternatively "duck-diving" or any clumsy diving with abdominal impact against the water can produce a similar result. Eye witnesses observe that there is no struggle by the victim who is found to be dead even if the body is immediately recovered. There may be instantaneous rigor (cadaveric spasm).

2. Laryngeal spasm

There is likely some element of laryngeal spasm in all drowning deaths. However in these cases there is no evidence of aspiration of liquid and there are the typical signs of an asphyxial death including facial cynanosis and petechial haemorrhages. The mechanism is thought to be sudden chilling of the neck and chest followed by immediate inhalation of water resulting in reflex spasm of the larynx, early unconsciousness and a rapid asphyxia. The possibility of an asphyxial death prior to entry into the water myst be excluded (e.g. homicidal strangulation).

3. "Dry drowning"

This terminology is not recommended. It derives from the division of drowning cases into "dry" and "wet" according to the condition of the lungs. However the finding of dry lungs indicates neither that water was inhaled nor that it was not. It is possible that water was inhaled, absorbed into the circulation and then death occurred prior to the onset of active pulmonary oedema. The confusing concept of dry drowning has been used to widen the spectrum of cases of vagal inhibition and laryngeal spasm bringing these valid concepts into some disrepute.

4. Delayed death ("secondary drowning", post-immersion syndrome)

Occasionally death occurs after an individual has been taken from the water and appears to have recovered from a near drowning. Autopsy discloses acute pulmonary oedema. This phenomenon has been reproduced in animal experiments. Later complications include pneumonitis, broncho-pneumonia and hyaline membrane disease together with renal failure secondary to haemoglobinuria.

DROWNING TESTS

There are no univerally accepted diagnostic laboratory tests for drowning.

1. Specific gravity of blood

This test was first proposed in 1902. It is suggested that a lower plasma specific gravity in blood from the left side of the heart when contrasted with blood from the right side of the heart reflects haemodilution produced during the drowning process.

2. Plasma Chloride

This test was first proposed by Gettler in 1921. The plasma chloride levels in blood from the left and right sides of the heart are compared. Haemodilution in fresh water drowning is considered to produce a lower chloride level in left heart blood when contrasted with right heart blood. Conversely haemo-concentration and chloride ion absoprtion in salt water drowning is considered to produce the reverse result.

3. Plasma Magnesium

This test was proposed by Moritz in 1944. High levels of plasm magnesium in left heart blood when contrasted with right heart blood is considered to reflect absorption on that ion from the drowning medium particularly salt water. None of the above tests are considered definitive although some workers believe that they can provide confirmatory evidence of drowning when the body is recovered and the tests performed within a few hours of death. Non-uniform and unpredictable changes in blood electrolytes which always occur after death render these tests less and less useful the longer the interval between death and recovery of the body.

4. Diatoms

Diatoms or Bacillariophyceae are a class of microscopic unicellular algae of which about 15,000 species are known (approximately half live in fresh water and the other half in sea or brackish water). Classification is based upon the structure of their siliceous valves. The cell structure is unique in that it secretes a hard siliceous outer box-like skeleton called a frustule which is chemically inert and almost indestructable being resistent to strong acids.

In 1941 Incze demonstrated that, during drowning, diatoms could enter the systemic circulation via the lungs. Their presence can be demonstrated in such tissues as liver, brain and bone marrow following acid digestion of the tissue.

The use of diatoms as a diagnostic test for drowning is based upon the hypothesis that diatoms will not enter the systemic circulation and be deposited in such organs as the bone marrow unless the circulation is still functioning thus implying that the decedent was alive in the water.

The test is limited by the difficulty of excluding the possibility of contamination. Diatoms are ubiquitous in the environment e.g. in the building industry and as dusting powder for rubber gloves. Additionally diatoms have been found in the organs of decedents not recovered from water, raising the possibility that diatoms may enter the circulation via the gastro-intestinal tract (as contaminants of foods such as salads, watercress and shellfish) or via the respiratory tract (diatoms are normally present in small numbers in the air).

The present consensus is that, given adequate precautions to prevent contamination, the demonstration of diatoms in organs such as bone marrow is strong corroborative evidence of death by drowning. This is true for decomposed bodies provided there is no gross mutilation. It should be confirmed that the species of diatoms found are the same as those present in the water from which the body was recovered (the diatom population varies seasonally with a major peak in the spring and a less pronounced peak in the autumn). A water sample should be obtained with a plankton net (alternatively collect 1-2 litres of water, add a few drops of iodine to kill the micro-organisms, stand overnight, decant with care and retain the concentrate for examination).

Examination of lung fluid for diatoms is of more limited value but their presence in large numbers provides corroboration of death by drowning.

EFFECTS OF IMMERSION

1. Sinking, putrefaction and refloating

A body in water will usually sink but because the specific gravity of a body is very close to that of water then small variations e.g. air trapped in clothing have a considerable effect on buoyancy. Having sunk to the bottom the body will remain there until putrefactive gas formation decreases the specific gravity of the body and creates sufficient buoyancy to allow it to rise to the surface and float. Heavy clothing and weights attached to the body may delay but will not usually prevent the body rising. Putrefaction proceeds at a slower rate in water than in air, in sea water than in fresh water and in running water than in stagnant water. The principal determinant is the temperature of the water so that in deep very cold water e.g. the North American Great Lakes or the ocean the body may never resurface.

For the Thames, Simpson offers the following guidelines for resurfacing times: June to August: 2 days; April, May, September and October: 3-5 days; November, December: 10-14 days; January, February; possibly no resurfacing. At water temperatures persistently below 45F there may be no appreciable decomposition after several weeks.

In the water the body floats face down with the head lower than the rest of the body so that lividity is most prominent on the head, neck and anterior chest. Lividity is often blotchy and irregularly distributed reflecting movement of the body in water. It is not intensive and appears a pink or light red colour. In cold water it can be dusky and cyanotic. It may be difficult to recognise due to swelling with water of the upper layers of the skin with resultant loss of translucency.

Putrefaction begins first within the areas of lividity i.e. the head, neck and anterior chest. It assumes a greenish bronze or dark brown colour; if exceptionally dark there is a tete de negre appearance. Putrefaction destroys any foam present in the airways and produces instead a reddish brown malodourous fluid containing bubbles of gas which is of no diagnostic significance (a "pseudo foam"). A similar appearing fluid appears in the pleural cavities associated with collapse of the lungs and this also has no diagnostic significance and does not necessarily reflect a pre-existing pleural effusion.

Once removed from water putrefactive changes advance with remarkable rapidity.

Adipocere which is a soap-like transformation of subcutaneous fat is common in bodies immersed in water usually appearing after some months; it may be present in as little as six weeks.

Occasionally bodies found in water develop so-called lime-soap nodules on the intima of veins, in particular the hepatic veins and on the endocardium. Similar nodules composed of calcium phosphate, calcium carbonate, neutral fat and proteinacous substances may be found in the skin of bodies recovered from water.

2. Anserina cutis (goose-skin)

This is a roughening or pimpling of the skin resulting from rigor or the erector pilae muscles most prominently on the thighs. It is of no diagnostic significance since it can occur in circumstances other than drowning, can develop in the interval between somatic and molecular death or can be a post mortem change.

3. Maceration of the Skin

Immersion in water produces progressive maceration of the skin which becomes blanched, swollen and wrinkled. It is first apparent in the skin of the fingerpads and then appears on the palms, backs of the fingers and back of the hand in that order. When fully developed it is most striking on the palms and soles. In water 50-60^o F early changes can be seen within an hour. Generally there are obvious changes within 24-48 hours but the process may be delayed for several days in winter. With developing putrefaction the epidermis including the nails peels off like a glove or stocking. Fingerprints may be easily prepared from the glove; reverse fingerprints may be prepared with some difficulty from the exposed dermis. The wrinkling and blanching of water-soaked skin in reflected histologically in water uptake with swelling of the epidermis progressing to epidermal detachment from the dermis.

Tattoos and scars are readily identified in the dermis following autopsy removal of the peeling epidermis. Occasionally chromogenic bacteria (bacillus prodigiosus and bacillus violaceum) invade the dermis of bodies in water after a period of at least one to two weeks and produce patterns giving the impression of tattoos.

4. Post Mortem Injuries

Having sunk to the bottom, a body drifting along the water bed will sustain a pattern of injuries reflecting its head down floating position (see above). Abrasions are typically found over the prominent points of the face, anterior trunk and extremities. A wide range of injuries may be produced by battering against rocks or by passing watercraft in navigable waters e.g. propellor blades (repetitive parallel chops). The body may be attacked by sharks, small fish, sea lice and other fauna. The soft parts of the face are particularly vulnerable to fish and crustaceans. Injuries may be inadvertently inflicted during the recovery of the body using grappling irons, hooks and ropes.

It is particularly difficult to distinguish ante mortem from post mortem injuries because on the one hand water immersion leaches the blood out of antemortem wounds while on the other hand post mortem wounds tend to bleed more readily than usual due to the fluidity of the blood (particularly in areas of dependent lividity e.g. face). Histological evidence of a polymorphy infiltrate indicates that the injury is antemortem and has preceded death by at least one hour. The absence of a tissue reaction does not exclude the possibility that the wound is ante mortem. The injuries must be interpreted in the light of the circumstances but even so definitive interpretation may be impossible. The presence of pulmonary fat or bone marrow embolism indicates that bony trauma is ante mortem but the absence of fat embolism is not proof that the trauma was post mortem.

5. Alcohol

Approximately two thirds of adult males found drowning have consumed alcohol. Blood alcohol concentrations in drowning victims in both fresh and salt water may be marginally decreased depending upon the volume of water inhaled and absorbed. Corroborative measurements on vitreous humour, urine or bile should be performed where possible.

6. Fleas and Lice

Fleas associated with a body can survive for up to 24 hours submerged. Lice survive for 12-48 hours.

7. Body Temperature

The body cools in water about twice as fast as in air (i.e. about 5^o F per hour) and reaches the temperature of the water usually within 5 to 6 hours and nearly always within 12 hours.

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1. References

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(good discussion of the investigative approach to these cases).

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(good raw data, but a not so good discussion).

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(the latest in laboratory tests for drowning, yet to be more widely and critically appraised).

7. Taylor L R, The Restoration and Identification of Water-soaked Documents, Journal of Forensic Sciences, 1986, 31, 1113 - 1118.
(good practical tip, describes freeze-drying method to recover water-soaked identifying documents on a drowning victim).

8. Diatoms in Taylor's Principles and Practice of Medical Jurisprudence, Ed. Mant A K, Churchill Livingstone, Edinburgh, 1984, p. 297 - 299.
(good brief review of the diatom test in drowning).