



Topical Update – The Hong Kong College of Pathologists

The Hong Kong College of Pathologists, Incorporated in Hong Kong with Limited Liability

Volume 15, Issue 2

July 2020

Editorial note:

Drowning often presents in various scenarios depending on the circumstances. This Topical Update provides a proper approach to the diagnosis. We welcome any feedback or suggestions. Please direct them to Dr. FOO Ka-chung (e-mail: k.foo@smd18.qmul.ac.uk) of Education Committee, the Hong Kong College of Pathologists. Opinions expressed are those of the authors or named individuals, and are not necessarily those of the Hong Kong College of Pathologists.

Drowning: A Rational Approach to its Diagnosis

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Introduction

Drowning is referred as “death occurring within 24 hours of a submersion incident”. Definition by World Health Organization is “the process of experiencing respiratory impairment from submersion or immersion in liquid”. [1,2] It is a form of asphyxia with a distinct pathophysiology and mechanism of death. It is also a diagnosis by exclusion, and therefore every piece of information should be regarded as crucial. Pathologists are obliged to work under Coroner’s jurisdiction in interviewing the next-of-kin (if available), reviewing antemortem medical records and preliminary findings provided by investigating officer, performing an autopsy as directed and compiling reports capable of addressing anticipated issues.

As Forensic Pathologists mostly deal with sudden and unexpected deaths, cases of drowning with unsalvageable outcome are often encountered.

Hospital Pathologists, on the other hand, are dealing with patients presenting a clinical picture in which death eventually occurred after vigorous cardiopulmonary resuscitation followed by development of various systemic complications, e.g. pneumonia, acute respiratory distress syndrome, multi-organ failure, disseminated intravascular coagulopathy, hypoxic-ischaemic encephalopathy etc.

Manner of Death

Information derived from the Coroner’s Report [3] and the Centre for Health Protection [4] suggested that majority of cases were accidental or suicidal in nature. Only a few were homicides. However, it should be remembered that a body found immersed in water does not necessarily imply a diagnosis of drowning. Nor its manner be automatically presumed basing on the prevalent trend. The deceased can die of natural conditions preceding or during submersion as well as

unnatural elements that contributed to the drowning process, explaining the failure of extrication from water versus genuine lethal trauma before or while in water. [5,6]

Pathophysiology

The mechanism of death is complex involving changes to viscera, biochemical alterations and also at a cellular level. The culprit is the medium imposing hydrostatic and osmotic effect to the lungs. [7] The acute change in intravascular volume with electrolyte imbalance is the consequence. Several stages of drowning present in response to the rising levels of carbon dioxide and decreasing oxygen tension in blood. Voluntary breath holding for about 1 to 2 minutes is followed by a stage of involuntary urge to breath with aspiration of fluid for about 1 to 3 minutes. Tonic-clonic seizures, together with some degree of respiratory activity, will occur in the next 1.5 minutes with eventual involuntary breath holding and terminal gasping before cessation of cardiac activity. [1]

It has even been mentioned that only a few inches of water is sufficient to drown a person, as in the case of sudden incapacitation by onset of acute illness while standing close to a washbasin or bucket. [5,6] It was reported that about 1 mL/kg to 11 mL/kg of water aspirated can result in drowning. [7]

A rare entity underdiagnosed in daily practice, or seldom made by pathologists, is referred as "dry drowning" or "immersion syndrome", with negative autopsy findings of typically drowned lungs due to severe laryngeal spasm, therefore preventing further intake while stimulating the sensitive receptors and subsequently triggering cardio-inhibitory reflexes (*Ebbecke reflex*, *Aschner reflex*, *Hering reflex*). [1,5,6,7,8]

Diagnosis of Drowning

The possibility of drowning should always be considered when a deceased was recovered from a body of fluid or the head was found submerged inside a medium of fluid. The deceased could be found near a body of fluid where it could be washed onto the rocky shore, beach, or riverbank.

Domestic environments such as bathtub also house this potential danger affecting all walks of life, especially for those who have chronic illness with sudden unexpected precipitation or the young. While the diagnosis of drowning could be straightforward one, such as a witnessed fall into water with subsequent submersion, it can be extremely difficult when critical information derived from the case is absent or inconclusive. Challenging scenarios can appear with unclear circumstances preventing proper formulation of the manner of death. Moreover, while findings derived from postmortem and ancillary investigations may collaborate with the diagnosis, it can be equally confusing when concomitant conditions are unveiled.

Presence of a natural condition which may contribute to death

Let's consider the following case:

A 51 year-old female was found collapsed underwater in a public swimming pool of about 1.4 meters deep and was certified dead despite intensive resuscitation. There was no eye witness leading to her collapse. Autopsy revealed severe ischaemic heart disease with no evidence of acute infarction. Both lungs were congested and oedematous but frothy fluid was absent probably due to suction during resuscitation. Cause of death is labelled as drowning as the overall features were compatible with drowning.

The presence of a co-existing medical condition, be it undiagnosed or known to the deceased, has to be evaluated carefully to attribute its extent of contribution to death. A sudden precipitation into cardiac arrhythmia explained the reason why a habitual swimmer is incapacitated and eventually succumbed in the water. From the investigator's point of view, possible legal issues regarding adequate supervision of the swimming environment may be raised which could lead to possible lawsuit and inquest. As such, the pathologist should be ready to address the extent of contribution of medical condition to the tragic outcome.

Medical background of the deceased has to be thoroughly reviewed including conditions such as asthma, epilepsy, cardiovascular conditions (e.g. Long QT syndrome type 1). Psychiatric history including substance abuse should also be elicited.

Presence of trauma which may be related to death

Another case is presented here:

An 87 year-old female was found floating off shore from a pier. She was known to be a habitual swimmer and there was no known chronic illness. There were multiple lacerations on chest and right upper limb. The thoracic cavity was breached and right lung had collapsed. Tinge of frothy fluid was noticed briefly by paramedics before transportation to mortuary. Autopsy revealed severe coronary stenosis and the left lung was mildly hyperinflated.

The presence of trauma may or may not be related to death as injuries inflicted can be produced ante-mortem or post-mortem. Assessment for vital reactions at the wound margin may be helpful to determine its nature.

All forms of injuries must be explained correlating inanimate objects in the environment. Sliding abrasions may be inflicted upon skidding down a slope while blunt force injuries may be a genuine assault. Self-inflicted injuries may occur in suicide as a back-up technique, for example, a stab to the chest or incised wound on the neck, yet it might at times mimic a homicide.

Dragging effects as a result of contact with river bed or ocean floor propelled by sea waves or tidal current is not uncommon and should be interpreted in light of such movement in water. Abrasions or lacerations may be found on forehead, dorsum, knees and toes. In addition, aquatic animal activity, such as crustaceans, will produce bites and nipping around orifices. The body, on the other hand, may be struck by watercraft or its parts including the propeller, predominantly located below the waist and over the extremities while the subject is maintaining a vertical position. It should be located posteriorly upon floating postmortem. [5,6] At times injuries

could be severe enough to hinder the diagnosis by producing serious disruption of the viscera. The presence of postmortem mutilation further complicate the diagnosis, let alone in jeopardizing the facial features and hindering identity as often encountered in mass fatalities.

Healthy adults who can swim rarely drown unless there is an intervening reason such as superimposed injury, fatigue or dangerous environment. The level of fitness, history of risk-taking behaviour, pre-swim activities, swimming ability and experience should be explored.

In the present case, the cause of death is labelled as drowning and suggested an accidental manner with sudden precipitation of undiagnosed cardiac condition, complicated by postmortem propeller injuries by marine traffic, evidenced by lack of blood infiltration at the site of traumatic amputation.

Let's consider another case:

An 80 year old male, who was an inmate of old aged home with multiple comorbidities confined to a wheelchair, was found submerged underneath river. He was last seen swaying around a footbridge about 3 meters above the river several hours earlier. Probable suicidal intention was identified. Autopsy revealed extensive comminuted fractures of the vault, subarachnoid haemorrhages and cortical contusions. Both lungs did not appear to be waterlogged.

Injuries may also be produced before or upon entering water and their extent have to be assessed. This could be related to subsequent question of survivability. In this case, considering the severity of the head injuries, it would appear that the deceased was unable to survive in water (or at most only a transient period) and succumbed rapidly. The cause of death is therefore attributed to head injuries upon falling with his top of head bumping the river bed.

Another case to ponder:

A 33 year-old female was found submerged about 20 meters off shore. Linear reddish

bruising was found on the anterior neck. The face and eyes were congested with petechiae. Small amount of frothy fluid was present. Both lungs were congested and oedematous. Dissection also revealed deep bruising of strap muscles suggestive of pressure applied to neck. Subsequent investigation revealed spouse's involvement with manual strangulation during a quarrel.

Suspicious injuries should be noticed which may be an act of homicidal drowning. In the present case, the cause of death is a combination of drowning and pressure on neck, with latter being a significant event rendering the deceased unconscious when pressure was applied and succumbed to the effects of immersion.

Presence of drugs which may be related to death

Let's consider the following case:

A 29 year-old male was found floating in the river reported by local residents. No personal property could be found. No suicide note was present. He was last seen alive by wife 3 days ago and was believed to have quarreled with a female acquaintance, exhibiting violent behavior and soon disappeared afterwards. Wife reported missing to Police the next day and his personal belongings were discovered in a shopping mall. Autopsy revealed features of drowning. Postmortem toxicology analysis showed presence of cocaine and its metabolite benzoylecgonine in blood. It was not known to the family whether he had a history of drug abuse.

Toxicology samples are crucial to exclude conditions that may mimic autopsy features of drowning, such as pulmonary oedema. It may help to exclude an accident, explain for failure to extricate or survival in water, as well as inferring an intention to end one's life or a deliberate intoxication. In the present case, analysis of hair samples was performed to address the issue whether he was exposed to illicit drug on a chronic basis and therefore exhibiting tolerance.

Presence of decomposition features may obscure the effects of drowning

Let's consider the following case:

A 32 year-old male was found in the reservoir exhibiting moderate decomposition changes. Suicide note was found in personal property placed neatly on the shore. Autopsy did not reveal any significant trauma or lethal disease conditions. Both lungs were not hyperinflated but huge amount of serosanguinous effusion was present in chest cavities. Police investigation also revealed a strong suicidal intention and third party was not involved.

Typical findings of drowning are often masked by decomposition changes. In addition, the time of death has to be determined during investigation. For fresh bodies examined at scene, corrective factors should be applied while measuring the core temperature against ambient temperature as the rate of cooling in flowing and still water are different. Casper's dictum refers to the rate of putrefaction after 1 week in air being equivalent to 2 weeks in water and 8 weeks burial in soil. The varying features of decomposition hint to the postmortem interval and is generally slower in cold water than a body discovered on land, but may be accelerated in bacterial laden stagnant water. As micro-organisms continue to disseminate and distribute throughout various body compartments, decomposition will be accelerated upon retrieval.

While the cause of death can remain unascertainable due to decomposition, the pathologist could nonetheless leave a remark stating the overall findings was not inconsistent with that of drowning. This is dependent on the degree of diagnostic certainty dictated by the available circumstances and likelihood of other intervening events, such as injuries (which could also be obscured by decomposition).

Let's consider another case:

A 69 year-old female with a history of psychotic illness was found floating in the sea, three days after her husband had reported missing to Police. No suicide note was found. Body exhibited early decomposition changes. Postmortem toxicology analysis revealed a

toxic level of amisulpride in the blood samples. As there was no concrete evidence about the suicidal intention or actual clinical progress on the psychiatric condition, it remained unclear whether the deceased fell into the water out of her intention.

Destruction of micro-architecture by decomposition permit considerable degree of postmortem redistribution of drugs which possibly account for the elevated levels in the specimen. The cause of death and manner can remain inconclusive.

Mysterious circumstances

Let's consider a case with apparently suspicious circumstances:

A 32 year-old male with a known history of mood disorder was found floating near a port. His leg was tied to a dumbbell. Suicide note was found at home. He was last seen alive two days ago and reported missing by family another two days later. The body exhibited early decomposition changes but the lungs appeared hyperinflated. Further Police investigation tracked the last whereabouts of the deceased including the use of surveillance camera in the vicinity and revealed no evidence of third party involvement. The shopkeeper selling the dumbbell clearly recalled visit by the deceased on the day of death.

Forensic Pathologists do not interpret a case relying solely on the autopsy findings. Circumstantial information can play a role to hint the pathologist appropriate features that should be looked for during scene and body examination. In the present case, there could be an underlying psychiatric vulnerability suggestive of a suicidal intent. A body with weight affixed to limbs can of course represent an unlawful disposal, but may as well indicate a determination to kill oneself. Examination of the knot tying at the involved body part is crucial.

For suspicious case a detailed investigation into the events before death is expected. The salient areas of such are briefly mentioned here.

Witness account

This is valuable and gives considerable weight to the case. For example, witnessed jumping into the water, signs of mental impairment, activities prior to submersion, the duration of immersion, bystander resuscitation with possibility of repositioning of body, accounts provided by lifeguard and nearby video surveillance, are all hints to the state of mind prior to drowning. [5,6] Homicidal drowning is rare unless one is being incapacitated by alcohol, drugs or physical weakness, or taken by an element of surprise such as being pushed unexpectedly into water. [9]

Scene and environment

Water temperature, current, terrain, water depth, underwater condition, floating objects, marine animal activities or plants, presence of safety and rescue measures are important to consider. A seemingly innocent river with slow volume of flow may harbor strong underwater currents creating significant eddies and vortex sucking the swimmer rapidly, coupled by additional injuries inflicted by submerged rocks and waterfalls, or falling log from trees nearby. [10]

Body floats owing to formation of putrefactive gas producing buoyancy and is affected by lung volume. It could even overcome weights added to the body in concealed homicide. The body will continue to sink as hydrostatic force exert pressure to the chest and abdominal compartments creating negative buoyancy. In extremely cold water with minimal bacterial activity, the body will never resurface and decompose through formation of adipocere. [1,5,6,7,8] Coupled together with witness account about the last seen at the point of immersion, an estimation of current speed and body drop rate (about 1.5 and 2 feet in salt and fresh water respectively) can allow back-calculation of the site of drowning in moving water, i.e. the distance from shore, which is useful for rescue and case reconstruction. [5,6]

For indoor environment a bathroom may present with wet, floor, wet towels and soap scum level in the tub (if water has been drained already). The presence of bucket and mop, and other cleansing material maybe an attempt to disturb the scene.

[5,6] A discovery of electrical appliances would call for a proper investigation to the possibility of electrocution.

Location of body

The place where body is discovered does not necessarily indicate the site of drowning. A body can be brought by a receding tide to the shore and there is always a possibility of drowning in another place, such as an indoor environment. [5,6,7] The body maybe disposed into the sea as an act of mimicking suicide. Differentiation between genuine drowning versus other causes; as well as fresh versus salt water immersion would be helpful. The appropriateness of the subject to the location is important. A restricted access may suggest unauthorized entry to the premises and should be investigated.

State of body

The condition of body regarding to its state of dryness or wetness, any attachment by aquatic debris and clothing identified are important. [5,6,7] Minute pieces of evidence pertaining to the identity, drug habit, personal property, weapon and suicide note should not be overlooked. Clothing and status of equipment, especially in diving related fatality should be examined. A naked body may be a deliberate act of hindering proper identification, or could be linked to a sexually motivated homicide. The body composition, water temperature, current action, type of clothing, method of water entry may all affect the presence or absence of clothing on body and should be interpreted with care. [6]

The presence of sand, seaweed or other vegetation should be documented and described, with the possibility of sampling for trace evidence and hinting the location of drowning in doubtful situations. A pair of shriveled and pale hands or feet can be found regardless of whether the individual was alive or not. Commonly referred as "washerwoman's skin", there is wrinkling and grayish white discoloration of skin at sites devoid of sebaceous glands. Histological features of swelling of epidermis keratinizing squamous epithelium, detachment of horny layer, fraying of keratin lamellae and vacuolation in the basal layer

are observed. There are reports in older literature with reference to such histological changes in an attempt to determine the postmortem interval, though subjecting to environmental factors of water type, temperature, movement, pollution and dermal characteristics of the subject. [11]

Hospital Pathologists are familiar with the appearance of hypostasis but such phenomenon would be present on face, upper chest and distal end of extremities. This is explained by dangling position adopted by the body with head and limbs pointing downwards owing its specific gravity while the posterior trunk is floating backup. [1,5,6,7] On the other hand, hypostasis can be minimal when exposed to fast flowing water. [5,6] For bodies lying in bath tub there may be a line of demarcation corresponding to the water level. [7] The importance of visiting a scene cannot be emphasized more.

Clear or blood tinged oedema is usually described as a plume of froth around the nose and mouth. It is non-specific in nature and consists of bronchial mucus, oedematous fluid, air and the drowning medium. The redness is accounted by the ruptured capillaries exuding into the respiratory tract. [7,8,] And most importantly it is transient in nature. In addition, slit, mud, sand, vegetation, algae and shell fragments may be present in bronchi and bronchioles visible both grossly and microscopically. [5,6]

Autopsy Findings

The role of an autopsy is to retrieve relevant findings that support the diagnosis. Not all the features will be present, depending on the nature of drowning process. Interpretation is only meaningful when combined with sufficient circumstantial information.

Emphysema aquosum

A pair of waterlogged lungs is a result of over-distension due to strenuous effort in an attempt to overcome oxygen depletion upon water influx. It is more prominent in the periphery and a combination of both lungs with effusion weighing more than 1000 g is usual. [7,8] There is also overlapping of medial edges in the anterior

mediastinum with indentation or imprints by the corresponding ribs. It is distinguished from chronic emphysema by protrusion of sectioned bronchial and vessels at the cut surface for the latter. Histology shows flattened inter-alveolar septa, dilated pulmonary alveoli and compression of septal capillaries. [11] Alveolar macrophages stained CD 68+ (smoker cells) may be washed from the alveoli to heart allowing its detection, as well as stimulation of certain subsets of myelomonocytes in lung tissues [8], though the validity of such remains low from a practical point of view. In addition, aspirated particles such as plant material in the distal bronchioles may be suggestive of ante-mortem aspiration.

Paltauf's spots

These are subpleural haemorrhages located in middle lobe fissure of about the size of a fingernail due to rupture of capillaries by overdistension and haemolysis by fresh water drowning.

Haemorrhage in neck muscles

The strap muscles and posterior occipital muscles may show tiny haemorrhages and altered histological appearance of the myofibrils with fiber degeneration, abnormal clumps of red material and ragged red fibers, owing to anoxic and ischaemic insult secondary to violent convulsive movements. At an ultra-structural level there is myofibrillar disruption and abnormal mitochondria. [12] A prudent approach is to exclude a mechanical cause before ascribing such to the effects of drowning.

Spleen

A contracted and anaemic spleen due to hypoperfusion and sympathetic stimulation with vasoconstriction is often nonspecific. [8]

Mastoid ear haemorrhages

Haemorrhage into ear compartment occurs as a result of pressure difference subsequent to blockage of Eustachian tube by water. [8,9]

Aspiration of fluid in the sphenoidal sinus:

“Svechnikov's sign” refers to presence of fluid (about 9 ml) in sphenoid and maxillary sinus by water penetration, which could also occur during postmortem. [7,8] It has been studied in literature with recent attempt to quantify and be detected by postmortem CT scan. [13]

Gastric dilatation

“Wydler's sign” refers to swallowing of water with resultant layer of sediment separating into three layers. This is also reported in recent postmortem imaging modalities with a certain degree of diagnostic confidence. [14] Oesophageal mucosal tears can be found occasionally due to distension by water. The presence of superficial radial ruptures of gastric mucosa is referred as "Sehrt's sign".

Ancillary Investigations

These tools can diagnose drowning with a higher degree of confidence, yet their limitations should be observed at the same time.

Histology

A differential staining of the intimal of aortic and pulmonary trunk is reported in the literature between saltwater and freshwater drowning. [15]

Immunohistochemical staining

Intrarenal aquaporin-2 (AQP2), intracerebral expression of aquaporin-4, aquaporin-5, HSP70, fibronectin are studied and reported with variable results. Surfactant protein A (SP-A) is produced by type II alveolar cells and showed increased expression with granular pattern in drowning case, despite that these stains could not readily differentiate between fresh and salt water drowning. AQP2, a channel protein for controlling flow of water molecules in the cellular interface, has shown apical expression in the apical membrane of the collecting in salt water drowning. [16] Arginine-vasopressin (AVP) was similarly expressed in the cytoplasm of renal tubules. Both have potentially served as markers to distinguish between salt and fresh water drowning, accounted by the increased binding and

expression in a hyperosmolar environment. [17] While differentiation is necessary to exclude unlawful disposal of body, this can occur "naturally" when the body was dragged by sea currents from river in some regions.

Biochemistry

There are literatures studying derangement of electrolytes including sodium, chloride, and magnesium between left and right ventricles basing on the effect of hypertonic and hypotonic action of the aspirated water in drowning, referred as the "Getter's test". Results were not promising and appeared to be controversial and not adopted for routine use. Strontium was also studied to a certain extent as an indicator of drowning. It has been reported that a difference of 75 µg/L between cardiac chambers could be an indicator of drowning. This test also falls short if the drowning medium has relatively low strontium concentration. [7,8]

Diatom test

This test has often been quoted as a gold standard for some to prove that drowning has occurred. Diatoms are microscopic unicellular algae coated with silica that exist in soil, water and atmosphere. If an individual is drowned in fluid which contains diatoms, they may be identified in the lungs and other organs if circulation is maintained at the time of aspiration. The diatoms can reach various organs such as brain, kidney, liver and bone marrow (femur being the most protected bodily compartment therefore its detection is generally regarded as true positive). The technique in collection of proper bodily samples should be strictly free from environmental contamination. Aided by the oxidizing property of strong acids, detergent or enzyme, the rest of the diatom tissue is consumed leaving a pellet to be centrifuged and then examined microscopically. [1,7,8,11,18] A sample of water must be taken from the suspected site of drowning for comparison. One should notice that a negative result does not rule out drowning as the cause of death.

Its application in cases with advanced decomposition explained why it is often regarded as a gold standard. [19] The confounding factor is

often the presence and concentration of diatoms in the environment plus the amount being aspirated. Unfortunately there is scanty environmental data about the species and frequency of their occurrence in local waters. Much data is needed for quantification for the profile of these algae in the environment, before designing an appropriate cut off value and proper positive species identification to achieve a reasonable sensitivity and specificity. Comparison may not be possible when the original site of drowning is unknown.

Postmortem imaging

Postmortem CT scan may show accumulation of aspirated fluid in the maxillary and sphenoidal sinuses (Svechnikov's sign), apart from detection of fluid in trachea and patchy ground glass opacities in the lung parenchyma. In another study, the presence of three layers consisting frothy material, fluid materials and dense component, visualized via different image contrasting features [13,14]. Care should be exercised during transportation as movement of body may result in reshuffling of content.

Conclusion

Despite ever expanding literature on the research about the pathophysiology and findings, as well as validity of ancillary investigations, pathologists are still facing challenges with vague circumstantial information, presence of ante/post-mortem trauma, decomposition changes, as well as non-specific autopsy findings. Nevertheless, as part of the indispensable team in death investigation, pathologists are obliged to take a proactive role in analyzing all available findings which might eventually shed light on any interpretable direction despite circumstantial evidence might still remain unclear. An inquest may be held after careful consideration by the Coroner and this has been the practice adopted to rebut unfounded allegations and refute rumors, when submitted evidence would be intensely examined. It is hoped that evidence presented and testimony of witnesses can address the appropriate issues and allow the next-of-kin to understand the circumstances before the final moment.

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