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Postmortem characteristics of drowning death in freshwater: a systematic review

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ABSTRACT

BACKGROUND: Drowning is the third leading cause of death by unintentional injury, accounting for 7% of all injury-related deaths worldwide. According to the latest World Health Organization Global Health Estimates, 236,000 people died from drowning in 2019.

AIM: This systematic review aimed to examine the clinical, laboratory, and other postmortem characteristics associated with death from drowning in freshwater areas.

MATERIALS AND METHODS: A systematic search of PubMed, Epistemonikos, and Cochrane Library databases was performed with no restrictions to find relevant articles. After the removal of duplicates, articles were reviewed, and information on the clinical, laboratory, and other postmortem characteristics of freshwater drowning deaths was extracted.

RESULTS: Of the 493 articles, 73 papers were considered relevant for full-text review. Of these, 22 articles met the inclusion criteria for the review. Most drowning deaths occurred in freshwater. Victims were males, with a male-to-female ratio of 8:3. External and internal clinical characteristics that are widely reported included signs of asphyxia such as cyanosis of the lips and bilateral fingernails, immersion signs such as washerwoman's hand, pink teeth, Neil's sign, Svechnikov's sign, Wydler's sign, and debris in the airways, and typical drowning signs such as froth in the airway, emphysema aquosum, and Paltauf spot.

CONCLUSION: The results of this study suggest that the presence of signs of asphyxia, immersion signs, and typical drowning signs such as froth in the airway, emphysema aquosum, and Paltauf spots were associated with drowning deaths in freshwater.

Keywords: autopsy; death; drowning; forensic pathology; freshwater.

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Посмертная характеристика случаев утопления в пресной воде: систематический обзор

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АННОТАЦИЯ

Обоснование. Утопление — третья основная причина смертности от непреднамеренных травм, что составляет 7% всех смертей в мире, связанных с травмами. Согласно последним глобальным оценкам Всемирной организации здравоохранения, в 2019 году от утопления умерло 236 000 человек.

Цель исследования — изучить клинические, лабораторные и другие посмертные характеристики, связанные со смертью от утопления в пресной воде.

Материалы и методы. Систематический поиск релевантных статей проводился без каких-либо ограничений в базах данных PubMed, Epistemonikos и Cochrane Library. После удаления дубликатов выполнен анализ статей с извлечением информации о клинических, лабораторных и других посмертных характеристиках случаев утопления в пресной воде.

Результаты. Из 493 статей признаны релевантными для полнотекстового обзора 73, из них 22 статьи отвечали критериям включения в исследование. В большинстве случаев смерть от утопления наступала в пресной воде. Среди жертв преобладали мужчины (соотношение мужчин и женщин 8:3). К хорошо известным внешним и внутренним признакам утопления относятся асфиксия (синюшность губ и ногтей), признаки погружения тела в воду («рука прачки», «розовые зубы»), признаки Нила, Свешникова и Уайдлера, инородные вещества в дыхательных путях, а также типичные признаки утопления, такие как пена в дыхательных путях, emphysema aquosum (так называемая водяная эмфизема) и пятна Пальтауфа.

Заключение. Наличие признаков асфиксии, погружения в воду и утопления (пена в дыхательных путях, emphysema aquosum, пятна Пальтауфа) свидетельствуют о гибели утопающих в пресной воде.

Ключевые слова: вскрытие; смерть; утопление; судебно-медицинская патология; пресная вода.

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淡水溺水的尸检特征：系统综述

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摘要

论证。溺水是意外伤害导致死亡的第三大原因，占全球所有与伤害相关死亡人数的 7%。根据世界卫生组织最新的全球估计，2019 年有 23.6 万人死于溺水。

研究目的是调查与淡水溺水死亡相关的临床、实验室和其他尸检特征。

材料和方法。在 PubMed、Epistemonikos 和 Cochrane Library 数据库中对相关文章进行了无限制的系统搜索。在删除重复文章后，对文章进行了分析，提取有关淡水溺水病例的临床、实验室和其他尸检特征的信息。

结果。在 493 篇文章中，发现有 73 篇与全文综述相关，其中 22 篇符合研究的纳入标准。大多数溺水死亡事件发生在淡水中。受害者中男性居多（男女比例为 8:3）。众所周知的溺水外部和内部征兆包括窒息（嘴唇和指甲发青）、身体浸泡在水中的征兆（“洗衣手”、“粉色牙齿”）、Neil、Sveshnikov 和 Wyidler 征兆、呼吸道异物以及典型的溺水征兆，如呼吸道泡沫、aquosum 肺气肿（所谓的水气肿）和 Palthauf 斑。

结论。出现窒息、浸水和溺水征兆（呼吸道泡沫、肺气肿、Palthauf 斑）表明是在淡水中溺水死亡。

关键词：尸检；死亡；溺水；法医病理学；淡水。

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BACKGROUND

Drowning is the process of experiencing respiratory impairments from submersion/immersion in liquid and is essentially a death by asphyxia [1]. Complete submersion is unnecessary for drowning, and submersion of only the nose and mouth for a sufficient period can result in death. According to the latest World Health Organization Global Health Estimates, 236,000 people died from drowning in 2019. Drowning is the third leading cause of unintentional injury death, accounting for 7% of all injury-related deaths worldwide [2].

Drowning deaths often occur during water recreational activities such as swimming, bathing, and boating, as well as in motor vehicle accidents. Suicide is another common cause of drowning and is often related to psychiatric illness. In addition, diseases such as epilepsy may play a role in drowning, and alcohol and drugs are often factors [3].

Drowning-related mortality rates are higher in low-income countries. In high-income countries, drowning often occurs in swimming pools, whereas in low-middle-income countries, it is more common in natural bodies of water such as ponds, ditches, rivers, lakes, drains, sumps, and water behind dams. Lack of awareness of water safety, risky behavior around water, and low perceived risk are also considered important factors [4].

A postmortem diagnosis of drowning was described as one of the most difficult in forensic medicine. [5]. In most cases, findings from the external examination and autopsy are nonspecific, and the interpretation of laboratory findings remains debatable in the scientific community [6,7]. Investigating deaths associated with natural bodies of water such as lakes, rivers, and oceans can be challenging because of their constantly changing characteristics. However, not all water-related deaths are caused by drowning; other factors such as extreme water and weather conditions, drug or alcohol

intoxication, or disease may be sufficient to cause death and thus preclude a postmortem finding of drowning [8]. A finding of death by drowning may be reached only after reviewing all external, internal, and laboratory findings from the forensic examination [7].

Not many studies have discussed drowning in freshwater areas [9].

AIM

Thus, this study aimed to review and characterize the clinical, laboratory, and other postmortem findings typical of drowning death in freshwater areas.

MATERIALS AND METHODS

A systematic review of the medical literature was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement Guidelines for the identification, screening, and inclusion of articles (Fig. 1). A database search of PubMed, Epistemonikos, and Cochrane Library was conducted on July 12, 2022 by three of the authors. The search terms were “drowning death” or “death drowning” with no database restrictions. Although we did not apply any restrictions on the publication type, status, language, or publication period in our search, papers in languages other than English and animal studies were excluded. Letters, editorials, reviews, and systematic reviews or meta-analyses were also excluded.

Three reviewers screened the identified articles based on the evaluation of the titles and abstracts. Articles whose titles and abstracts did not meet the inclusion criteria were excluded. Differences in the opinion among the three reviewers regarding

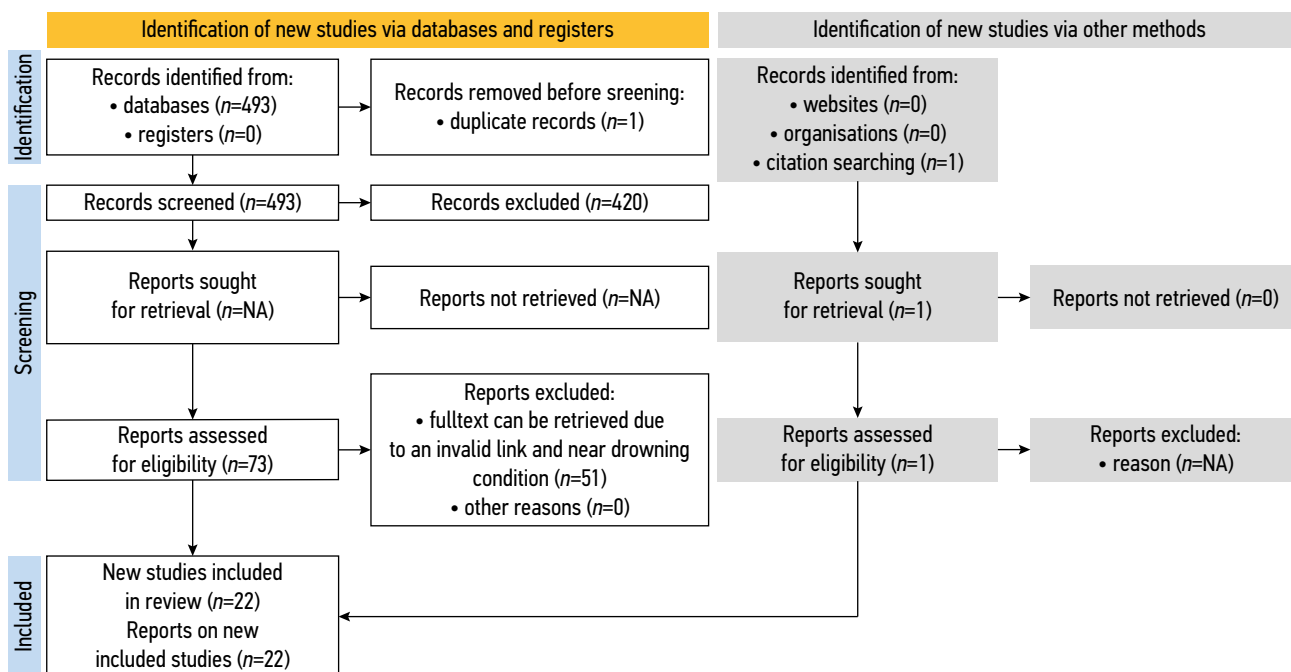


Fig. 1. PRISMA flow diagram.

the inclusion of articles were discussed until an agreement was reached. After the first screening, the full texts of the articles were reviewed for a final assessment of eligibility for inclusion in the study.

During the final assessment, articles were evaluated based on the level of evidence, quality, and risk of bias. The quality of articles was evaluated using the Joanna Briggs Institute critical appraisal, which was used to categorize each article as include, exclude, or need information. Only those articles categorized as include were analyzed and reported in this study. After screening, feasibility, and assessment of quality and risk of bias, data were extracted from all included articles. Important findings from each article were recorded, and data were synthesized. Data were extracted by three authors independently, and all extracted results were cross-checked. The extracted data were as follows: 1) clinical postmortem findings, 2) laboratory postmortem findings, and 3) other postmortem findings on death from drowning in a freshwater area.

RESULTS

The systematic database search considered 493 papers after duplicates were removed. After a review of the papers by titles and abstracts, 73 underwent a full-text review. A total of 51 papers were excluded after a full-text review, leaving 22 articles that met the inclusion criteria for the review (Fig. 1).

Most drownings occurred in freshwater. Most victims were male, with a male-to-female ratio of 8:3. In some cases, bodies were found in the state of decomposition. In general, in freshwater drowning, external and internal clinical characteristics that are widely reported include signs of asphyxia such as cyanosis of the lips and bilateral fingernails and signs of immersion in the form of washerwoman's hand, pink teeth, Neil's sign, Svechnikov's sign, Wydler's sign, presence of debris in the respiratory and digestive tracts, pericardial effusion, and heart dilatation. Meanwhile, the typical external and internal findings of drowning include froth exuding from the nostrils and mouth into the respiratory tract due to a mixture of air, water, and mucus, forced breathing when drowning, and emphysema aquosum and Paltauf spots due to the rupture of the alveolar walls caused by increased pressure resulting from forced expiration when drowning. Diatom examination is also performed in most cases to assist in the identification of drowning.

In saltwater drowning, in addition to the findings above, a study reports the presence of deposited seawater component elements on enamel and increased adhesion of phytoplankton to the enamel surface. In addition, several studies found bilateral pleural effusion and pulmonary edema. If we look at the size of the bilateral pleural effusion, saltwater drownings have more significant bilateral pleural effusions than freshwater drownings. In addition, saltwater drownings have significantly more pulmonary and intrathoracic weights than freshwater drownings. Summary details of the studies are displayed in Supplement 1.

DISCUSSION

Recently, the role of forensic pathologists has expanded beyond criminal justice to include public health and safety. Forensic pathologists are in a unique position to clarify the cause and manner of sudden unexpected deaths [18]. Drowning is a significant and neglected public health problem worldwide [1]. The mechanism of death by drowning is complicated by the involvement of asphyxia and filling of the airways with fluid, with associated hydrostatic and osmotic effects. Although autopsy findings among drowning cases are usually characteristic, they are often not diagnostic [4].

This study described rates of drowning death that were higher in men than in women. The higher incidence in men is likely caused by increased exposure to risky situations, increased risk-taking behavior, and greater involvement in activities outside the home [4].

Decomposition involves two processes, autolysis (destruction of cells and organs by intracellular enzymes) and putrefaction caused by bacteria and fermentation. Decomposition begins approximately 24 h after death, showing a greenish color in the lower right abdomen. It gradually becomes more visible, spreads across the abdomen and chest, and causes a foul smell. According to Casper's law of decomposition, the environment where the body is left affects the decay process such that the proportional ratio of decomposition in air, water, and soil is 1:2:8 [7].

Washerwoman's hand is characterized by pallor with wrinkling of the palms, soles, fingers, and toes. It starts on the fingertips, moves to the palm, and then spreads to the back of the hand. The skin gets thicker, wrinkled, whitened, and moistened (Fig. 2). These changes result from cutaneous absorption of water apparent at the fingertips, which characterizes immersion [15]. Although the washerwoman's



Fig. 2. Washerwoman's hand [8].

hand can emerge in 20–30 min after immersion/submersion, it can slowly disappear upon exposure to the open air and may not be apparent at autopsy. In forensic pathology, pink teeth have often been observed in drowning victims. The reddish tooth discoloration involves the diffusion of blood into the pulp in the dentinal tubules. Environmental conditions, particularly humidity, play an essential role in the development of pink teeth [7].

Neil's sign is a black field that is caused by bleeding into the middle ear cavity and blood adherence to the mastoid process; it is likely caused by pressure changes during drowning. Bleeding points found on the mucous membranes of the mastoid bone and middle ear are strong indications of drowning [7]. In a body recovered from a natural water environment, aquatic debris such as silt, mud, sand, gravel, vegetation, or algae may adhere to the airways and stomach (Fig. 3). Svechnikov's sign is characterized by fluid in the sphenoid sinus. This happens because the enhanced respiratory stimulus that occurs during dyspnea causes uncontrollably large amounts of fluid to enter the sinuses and airways. Wydler's sign is a three-layering formation found inside the stomach: food particles at the bottom, a medium liquid phase, and a foamy high phase made up of a combination of drowning fluid and tracheal secretion [15].

Froth in the airways was commonly reported in external and internal examinations of drowning victims. It is caused by the mechanical action of terminal respiratory efforts caused by forced breathing when drowning, resulting from the mixture of air, water, bronchial mucosa secretions, and surfactant in the lungs. On examination, extravasated blood from alveolar capillary rupture is the likely source of the pink or red-tinged froth (Fig. 4) [8]. The foam passes out the airways retrogradely and is a typical fungiform structure in front of the mouth and nostrils [15].

Emphysema aquosum is frequently highlighted in forensic literature as an important drowning sign, and accompanying lung changes must be correctly interpreted [15]. As a result of the airways closing during expiration, increased phlegm production and foam creation cause the hyperinflated lung as a valve mechanism. These mechanisms create the image of ballooned lungs filling the pleural cavities and reaching over the pericardium with their edges (Fig. 5). Imprints of the ribs on the lung surface

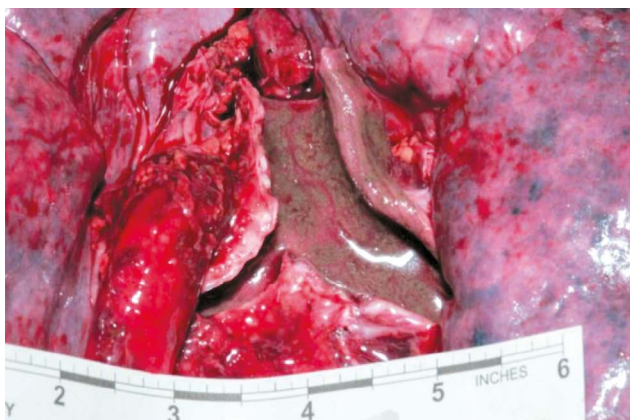


Fig. 3. Aquatic debris in the tracheobronchial tree [8].



Fig. 4. Froth in drowning victim [8].

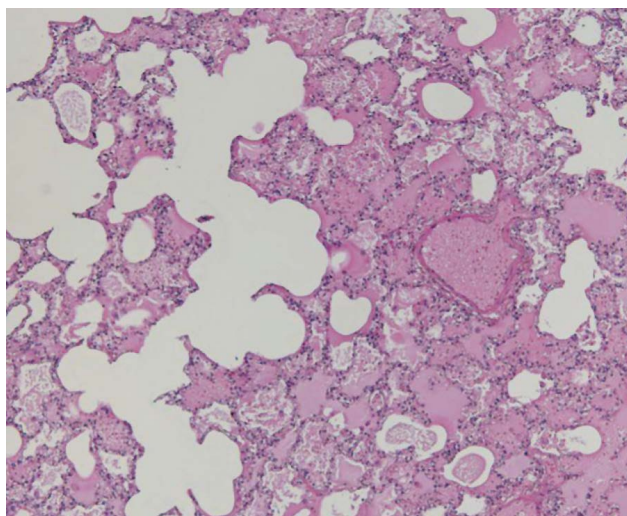


Fig. 5. Emphysema aquosum and intra-alveolar edema [8].

can often be seen. Histologically, the overinflated lungs present flattened and ruptured interalveolar septa surrounding blister alveolar cavities. In addition, anemic and normally perfused areas alternate in the lungs, whereas the alveoli–capillary membrane is damaged. The severity of this injury is proportional to the duration of the drowning process. Other signs of pulmonary hyperinflation include washed-out rhexis bleeding under the pleura, called Paltauf's spot [15]. Paltauf's spot refers to bleeding spots caused by increased pressure, leading to the rupture of the alveolar walls, mostly found on the anterior surfaces and borders of the lung, and can be found in the subpleural if there has been further leakage or rupture [7].

Diatoms are unicellular algae belonging to the class of Bacillariophyceae, which includes more than 15,000 species living in fresh, brackish, or sea water. Diatoms are inhaled during drowning; once in the bloodstream, they can reach the organs. If extracted and identified using strict protocols, these organisms are good markers of death by drowning.

CONCLUSIONS

This study suggests that characteristics associated with drowning death were the presence of signs of asphyxia such as cyanosis, immersion signs such as washerwoman's hand, pink teeth, Neil's sign, Svechnikov's sign, Wydler's sign, and debris in the airways, as well as typical drowning signs such as froth in the airway, emphysema aquosum, and Paltauf's spot. To recognize and diagnose drowning death, identifying characteristics should help forensic pathologists.

ADDITIONAL INFORMATION

Supplement 1. Study results that meet the selection criteria. doi: 10.17816/fm16113-145993

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