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# Forensic analysis of morphological changes in death due to drowning

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The present study aims to track the frequency of detection and characteristics of some of the main morphological changes observed during the autopsy of corpses that died as a result of drowning. A total of 151 forensic medical examinations reports of non-decomposed corpses diagnosed with drowning, were reviewed and for each case, the type of water body, the sex and age of the corpse, and some of the main autopsy findings related to the diagnosis of drowning were recorded – cyanosis, subconjunctival hemorrhages, foam, lung overinflation, subpleural hemorrhages, Sveshnikov‘s sign with presence or absence of diatoms and other foreign bodies. Analysis of the obtained results and data from reviewed literature clearly shows that there is no single morphological sign that is diagnostically specific only for drowning. The results of the study contribute to expanding knowledge about the main morphological changes observed in drowning, which significantly aids daily forensic medical practice.

*Key words:* drowning, mechanical asphyxia, autopsy findings, forensic examination

## Introduction

Drowning is a type of mechanical asphyxia that results from aspiration of liquid into the airways and lungs with the subsequent development of cerebral hypoxia. Death by drowning is an unnatural (violent) death, most commonly accidental, but it can also be a suicide, and in some rare cases, a homicide [14, 22, 31]. According to the World Health Organization, about 300,000 people die each year worldwide as a result of drowning [34]. Literature sources distinguish several predisposing factors as having a significant role in the occurrence of this type of accident (swimming in rough seas, alcohol use, presence of acute and chronic diseases, etc.) [24, 35].

It should be noted that not every cadaver found in a water environment died as a result of drowning. In the forensic literature, a general term is found – immersion death, which refers to bodies found in water. Some authors propose classifying these cases into several groups in relation to the cause of death, for example: death from natural causes during or before entering the water; death due to trauma during or before entering the water; death due to drowning, where several variants are also possible – when drowning occurred after trauma or pathological conditions that have left the victim in a helpless state (secondary drowning) and when it is not accompanied by any other event (primary drowning) [7, 29, 33].

In many cases, it is difficult to diagnose mechanical asphyxia due to drowning because there are no specific autopsy findings. It should be emphasised that there is no sign specific to drowning, so all findings related to drowning must be interpreted in the context of the circumstances in which death occurred. Some authors believe that drowning is actually a diagnosis of exclusion [3, 12, 14, 19, 22, 36].

When a corpse is discovered in a water environment with suspicion of drowning, two main groups of findings should be clearly distinguished – classic signs of asphyxiation death and signs indicating that the body has been in water for a certain period of time (signs of immersion). The main morphological changes observed in cases of various types of asphyxia (including drowning) are cyanosis, petechial hemorrhages on the conjunctivas, sometimes on the skin of the face and torso, on the serous membranes of the internal organs, incontinence of the sphincters of the pelvic organs, the presence of liquid blood, venous stasis in the internal organs, anemic spleen, edema of the brain and lungs, and others. It should be noted that the presence of these morphological changes must be analyzed with special attention, since they can also be observed in other causes of death than asphyxia, respectively, drowning. The group of signs that indicate the body was in an aquatic environment, such as piloerection, maceration changes on the skin, saponification, etc., are not conclusive evidence that death occurred due to drowning. On the other hand, those signs provide important information about the post-mortem submersion period [3, 7, 8, 12, 14, 22].

It is particularly difficult to establish the diagnosis of drowning in decomposing corpses. The process of decay is usually slower in an aquatic environment, especially in cold water, but it also depends on many other factors [3, 35]. It has been established that a body removed from the aquatic environment develops significantly faster decay processes. Therefore, according to the literature and forensic practice, it is important that after removal from the water, the body should be cooled as quickly as possible and an autopsy be performed within a short period of time [3, 8, 22, 35]. Saponification, as a specific preservation process of corpse decomposition occurring in an aquatic environment, can preserve both the anatomical integrity of the corpse and the possibilities for conducting additional examinations [3, 22].

Typically, external examination of the body of an individual who has died from drowning may reveal certain signs that are not strictly specific to this diagnosis - froth (foam) in front the nose and mouth orifices and along the airways, petechial hemorrhages on the conjunctivas (subconjunctival hemorrhages), cyanosis, and others. The foam, found around the nose and mouth and along the respiratory tract, is considered by some authors to be a specific sign of drowning and represents an important diagnostic indicator [14, 17, 19, 22, 31, 35, 37]. Facial cyanosis (sometimes also of the neck and chest), as well as subconjunctival hemorrhages, are not present in all cases of drowning and can also be a sign of other types of mechanical asphyxia or a pathological process leading to death [3, 22, 35].

Internal examination of the corpse may reveal certain morphological changes that aid in a more accurate diagnosis of drowning: overinflation of the lungs, subpleural hemorrhages, presence of fluid in the sphenoidal sinus (Sveshnikov‘s sign), presence of watery fluid in the stomach and duodenum, presence of free fluid in the pleural and peritoneal cavities (Moro‘s sign), and others [8, 22, 31, 35]. A number of authors believe that morphological changes, especially in the lungs, differ between drownings in fresh and salt water. This is related to the pathophysiological processes that are observed when aspirating a hypotonic solution (fresh water), and those when aspirating a hypertonic solution (salt water) [9, 14, 17].

The overinflation of the lungs is one of the main morphological signs observed in drowning. When drowning occurs in fresh water, it passes in large quantities through the alveolar-capillary membrane into the bloodstream. With this mechanism, the lungs appear very inflated (similar to a soaked sponge), at the same time their cut surface appears relatively dry, but when pressed, a foamy liquid is released. This is the morphological type of the lung's inflation that some authors defined as a hyperaerated form and corresponds to the concept of "emphysema aquosum" or the more accurate term "emphysema spumosum" (spongy emphysema). It is important to note that this type of emphysema differs from disease-related emphysema, in which typical bullae are usually found, and the cut surface shows prominence of the cut bronchi and blood vessels [7, 8, 14, 19, 22, 29, 35, 36].

When drowning occurs in salt water, due to the fact that it is a hypertonic solution, the water component of the bloodstream passes through the alveolar-capillary membrane and is retained in the alveoli themselves. These processes lead to a different morphological appearance of the lungs - they are markedly swollen, heavy, and a large amount of fluid leaks from their cut surface. Some authors call this form of overinflation hyperhydremic, while others use the term edema aquosum [8, 19, 22, 35, 36].

The term "dry drowning" is often encountered in literature, which is associated with the corresponding morphological finding of "dry lungs." In these cases, the lungs show no pronounced signs of acute distension, no significant increase in their weight, and their cut surface appears dry. As reasons for this finding, some authors highlight mechanisms such as laryngospasm, vago-vagal inhibition due to water contact with the upper respiratory tract, cardiac arrest, and others [9, 17, 19]. Other authors believe that the terms „dry drowning" and „dry lungs" should not be used in connection with drowning, as they do not correspond to the definitions of this type of mechanical asphyxia, suggesting instead that such autopsy findings likely indicate a cause of death other than drowning [16, 27, 30].

Typically, two main types of subpleural hemorrhages can be found on the lungs: pinpoint, petechial (small) hemorrhages, known as Tardieu‘s spots (hemorrhages), and larger, diffuse hemorrhages with indistinct borders, known as Paltauf's spots. According to some authors, Tardieu‘s spots predominate in cases of saltwater drowning, while Paltauf‘s spots are more commonly observed in freshwater drowning [3, 8, 22, 31, 35, 36].

The presence of fluid in the sphenoid bone sinus (Sveshnikov‘s sign) is a common occurrence in drowning cases [1, 8, 15, 22, 35, 36]. Some authors believe that the sign is positive even when the body has been in water without drowning being the cause of death [3, 37]. The amount of accumulated fluid in the sphenoidal sinus varies and depends primarily on the volume of the sinusoidal cavity itself. The fluid can be aspirated with a syringe and examined for the presence of diatoms and other foreign bodies [3, 15, 22, 35]. Diatom analysis can also be performed on other biological samples taken from the corpse during autopsy, such as lung tissue, bone marrow, liver, and others. The diatom test should be analyzed with particular attention, as there are a number of possibilities for false results. These can be due to many factors, such as contamination during collection and subsequent processing of the samples, passive penetration of diatoms into the body, the degree of postmortem changes in the corpse, respectively, postmortem interval, what materials (body liquids and tissue) from the corpse are subjected to examination, etc. The diatom test can be significantly useful in the process of diagnosing drowning, however, it should not be used alone, but in combination with other established evidence, such as the circumstances of death and discovery of the corpse, morphological findings during autopsy, etc. [12, 22, 28, 35].

Among the literature, there are also some additional autopsy findings in cases of drowning: Wydler‘s sign (separation of stomach contents into three components), Sehrt‘s Sign (micro-ruptures of the gastric mucosa), Neil‘s sign (hemorrhages in the middle ear cavity), and others [1, 9, 14, 28, 36].

Given the difficulties in diagnosing death due to drowning, the present study aims to track the frequency of detection and characteristics of some of the main morphological changes observed during the autopsy of corpses that died as a result of drowning.

## Materials and Methods

A total of 151 forensic medical expertise for autopsies of non-decomposed corpses diagnosed with drowning, conducted at the Clinic of Forensic Medicine at St. Marina University Hospital in Varna, Bulgaria, during the period 2008-2024, were examined.

In all forensic case, including drowning cases, the preliminary part of the expert examination indicates the circumstances of the death or discovery of the corpse, as well as available data regarding the victim, such as health status, chronic alcohol or drug use, etc. The external examination of each corpse usually includes an examination of the clothes, identification of postmortem changes (including maceration changes) and the degree of their development, detailed description of all traumatic injuries and their characteristics. The internal examination of the corpse is carried out by applying classical section techniques with a description of the macroscopic findings, and in the cases of bodies found in an aquatic environment, often the sphenoidal sinus is also opened. In some cases, additional examinations are carried out - histological and toxicological analysis, as well as a diatom testing.

With a focus on the purpose of the present study, only the following data were extracted and analyzed from forensic medical examination reports for each of the cases, diagnosed as drowning:

- ***The type of water*** the body was found in (saltwater or freshwater), the ***sex and age*** of the corpse.
- ***Cyanosis and subconjunctival hemorrhages***: these signs were recorded as present or absent.
- ***Foam (froth)***: this sign was considered present not only when found around the nose and mouth but also when discovered along the upper respiratory tract.
- ***Overinflation of the lungs***: cases were divided into three categories based primarily on the condition of the cut surface: cases where the lungs were heavy, markedly distended, and copious frothy (edematous) fluid spontaneously flowed out or with pressure from their cut surface were classified as the hyperhydremic form; cases where the lungs were enlarged, with a dry cut surface and released foamy fluid upon compression, were classified as the hyperaerated form; cases

where the morphological finding of the lungs could not be definitively assigned to either form were classified as a mixed (intermediate) form.

- ***Subpleural hemorrhages***: cases were divided into four groups based on this sign: absence of hemorrhages; presence of only petechial hemorrhages (Tardieu's spots); presence of large, diffuse hemorrhages (Paltauf's spots); presence of both petechial and larger hemorrhages.
- ***Sveshnikov's sign***: cases were divided into three groups based on this indicator: cases where the sign was not examined, presence of fluid, and absence of fluid in the sphenoidal sinus. In the practice of the our clinic, fluid from the cavity is aspirated with a sterile syringe for subsequent microscopic examination to detect ***diatoms and other foreign particles***, which was also recorded in the present study. For this purpose, the usual practice of our clinic is to perform direct microscopy of the sphenoidal fluid. In rare cases, we use other kind of fluid (for example, blood) or tissue samples (lungs, liver, kidney, bone marrow), which makes it necessary to perform chemical destruction to remove the organic component and prepare permanent microscope slides. The results of the test were limited to recording the "presence" or "absence" of diatom forms, sand grains, parts of plant origin, and other particles. Regarding diatom forms, in some rare cases, to determine the genus of the found diatoms, we use ADIAC - Diatom Image Database [4]. This step was usually applied only in cases where it is necessary to compare the diatom forms found in the corpse with those found in the water where drowning may have occurred.

Statistical analysis of the obtained data and results, as well as the creation of corresponding tables and graphs, was performed using Microsoft Excel®.

## Results

During the period 2008-2024, a total of 3364 autopsies were performed at the Clinic of Forensic Medicine at St. Marina University Hospital, with 14.12% of them being cases of mechanical asphyxia. Drowning cases constituted 4.49% of all autopsied cases and 31.79% of all cases of death due to mechanical asphyxia (**Fig. 1**).

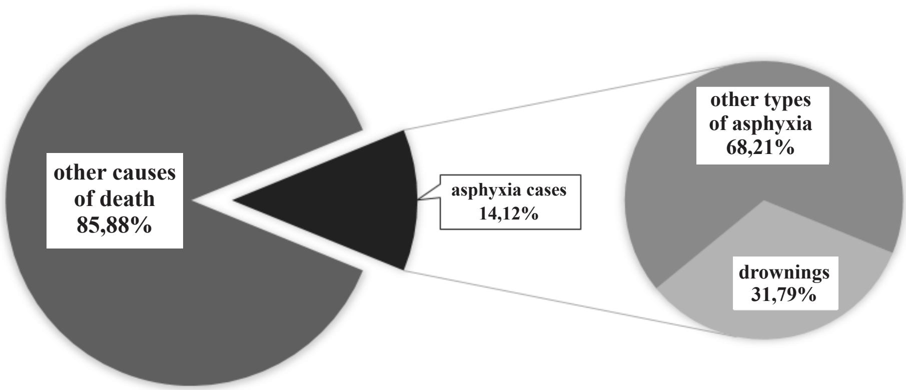


**Fig. 1.** The percentage distribution of asphyxia cases (as drownings and other types of asphyxia) relative to all cases for the period 2008-2024

Regarding the water in which the incident occurred, 72.85% of cases involved drowning in saltwater (Black Sea and associated Varna Lake and Beloslav Lake), and 27.15% involved drowning in freshwater (reservoirs, rivers, irrigation and drainage canals, springs, and others). The distribution of drowning cases by sex and age of the deceased is presented in **Table1**.

**Table 1.** *Distribution of drowning cases by sex and age groups.*

| | | |
|---|---|---|
| n = 151 | n (%) | |
| | **Male** | **Female** |
| | 122 (80,79%) | 29 (19,21%) |
| | | |
| | **age group (years)** | **n (%)** |
| | 1-20 | 18 (11,92%) |
| | 21-40 | 43 (28,48%) |
| | 41-60 | 38 (25,17%) |
| | 61-80 | 41 (27,15%) |
| | 81-89 | 11 (7,28%) |

Upon examining the external signs associated with the diagnosis of drowning, it was found that cyanosis and subconjunctival hemorrhages were observed in 27.15% and 29.80% of all drowning cases, respectively. Foam (including along the airways), which is one of the main signs of mechanical asphyxia due to drowning, was found in 80.13% of cases.

The different forms of overinflation of the lungs were observed in the following percentages: hyperaerated form in 11.26% of cases, hyperhydremic form in 35.10%, and mixed form in 53.64%. Subpleural hemorrhages, on the other hand, were not found in 21 drowning cases (13.91%), while Tardieu's spots were observed in 39.74%, Paltauf's spots in 17.22%, and both types of hemorrhages in 29.14% of cases.

Given the connection between a particular form of overinflation of the lungs and the type of subpleural hemorrhages with the water in which drowning occurred (freshwater or saltwater), **Table 2** presents the percentage distribution of these macroscopic findings.

**Table 2.** *Percentage distribution of the variations of overinflation of the lungs and subpleural hemorrhages in drowning cases in freshwater and saltwater.*

| | | **salt water** (n=110) | **fresh water** (n=41) |
|---|---|---|---|
| **Lung overinflation** | **hyperaerated form** | n=11 (10,00%) | n=6 (14,63%) |
| | **hyperhydremic form** | n=43 (39,09%) | n=10 (24,39%) |
| | **mixed (intermediate) form** | n=56 (50,91%) | n=25 (60,98%) |
| | | | |

| | | | |
|---|---|---|---|
| **Subpleural hemorrhages** | **Tardieu’s spots** | n=56 (50,91%) | n=4 (9,76%) |
| | **Paltauf’s spots** | n=10 (9,09%) | n=16 (39,02%) |
| | **Presence of both Tardieu‘s and Paltauf‘s spots** | n=29 (26,36%) | n=15 (36,59%) |
| | **absence of hemorrhages** | n=15 (13,64%) | n=6 (14,63%) |

Of all 151 drowning cases, the sphenoid bone sinus was examined for free fluid in 143 of them, with such fluid being found in 96.50% of the examined cases. Regarding the presence of diatoms and other particles, 98 drowning cases were tested by direct microscopy of the sphenoidal fluid, and diatom forms and other foreign bodies were found in 87.76% of them.

## Discussion

From the 1960s to the present day, the Clinic of Forensic Medicine at the St. Marina University Hospital in Varna and the corresponding department at the Medical University – Varna, have been actively involved in the forensic medical aspects of drownings in the Varna region. Two studies on this topic have been published: one by Yovchev I, covering drowning cases from 1963-1972 [35], and another by Radoynova D. et al., focusing on the period 1998-2007 [23].

Analysis of the data from the present study and comparison with the results of the aforementioned two studies showed that for the period 1963-1972, drowning cases autopsied at the forensic medicine clinic represented 9.23% of all autopsies, decreasing significantly to 5.41% for the period 1998-2007, and representing 4.49% of all autopsies for the period of the present study. This indicates a clear trend of decreasing incidents of this type in recent years [23, 35]. These data are also confirmed by the general statistics on drowning mortality in Bulgaria for the period 2010-2023, where after a peak in 2014, when cases were 2.2 per 100,000 people, in 2023 they were 1.3 per 100,000 [20].

Regarding gender distribution, both in the present study and in the other two conducted at the clinic for previous periods, the male to female ratio was approximately 4:1. The study for the period 1963-1972 found that 68.90% of the reviewed drowning cases were under 35 years of age, with 8.64% being children under 10 years. In the study during 1998-2007, the average age of drowned individuals was 43.55 ± 2.5 years, and children aged up to 14 years constituted 6.12% of all deaths due to drowning [23, 35]. In the present study, the highest percentage of drownings was observed in the 21-40 age group, and deaths due to drowning under 20 years of age represented 11.92%. This indicates that there is no significant change in age distribution, and individuals in young adulthood (around 40 years) continue to be the most affected age group.

Analysis of the data from the present study regarding autopsy findings in drowning revealed that cyanosis and subconjunctival hemorrhages were observed in less than 1/3 of the cases. These data differ significantly from those obtained by Yovchev I, where cyanosis was found in 69.17% of cases and conjunctival hemorrhages in 65.78% [35]. On the other hand, other similar studies in the literature show that subconjunctival (scleral) hemorrhages are found significantly less frequently compared to the present study. In a study of 171 autopsies of drowned bodies, conjunctival hemorrhages were observed in only 4.1% [24], while in another study of drowning cases in children aged 5 months to 17 years, this percentage was about three times higher (12.7%) [26]. Some authors believe that conjunctival hemorrhages might disappear during the body's stay in water due to hemolysis, especially in freshwater. Also, they may not be noticeable in cases where there is conjunctival desiccation and the appearance of Larcher's spots [2, 5, 22]. The significant differences in the frequency of these findings across various studies are likely due to a number of factors, such as the duration of the asphyctic process, post-mortem interval, anatomical and physiological characteristics of the individuals, and others.

In the present study, the foam (foamy content) was present in a significantly high percentage of the examined cases (80.13%). Yovchev I.'s study observed foam in only 35.71% of drowning cases. This significant difference between the two studies may be due to the fact that in the present study, foam was observed not only at the orifices of the mouth and nose but also within the airways [35]. A study conducted at the Department of Forensic Medicine at the University of Helsinki observed foam at the respiratory orifices in 17.3% of drowning cases and in the respiratory tract in 46.5% [18]. Some authors note that for a certain period after death, the foam may no longer be detectable [3, 19]. In another similar study, foam was found in the respiratory tract in 73.3% of drowning cases, while external foam was present in only 4.0%. Complete formation of external foam was observed by the same authors only in cases where the body's stay in the water was less than 24 hours [25]. In summary, foam is an important sign of drowning, the presentation of which can depend on various factors (post-mortem interval, duration of body submersion in water, resuscitation efforts, etc.). When foam is found shortly after death and other causes for its formation (diseases, intoxication, etc.) are excluded, this sign represents an important criterion in the process of diagnosing death due to drowning.

The overinflation of the lungs in the present study was examined in three categories based on the morphological appearance of the lungs and their cut surface. In more than half of the reviewed cases, the form of overinflation was not clearly presented and could not be definitively classified as hyperaerated or hyperhydremic. Some authors associate the hyperaerated form with freshwater drowning and the hyperhydremic form with saltwater drowning, and the explanation is related to the pathophysiological processes associated with the aspiration of hypotonic, respectively, hypertonic solution [9, 14, 17]. The results of the present study indicate that in only 6 out of 17 cases of hyperaerated form did drowning occur in freshwater. On the other hand, the hyperhydremic form represented 35.10% of all drowning cases and was found in 39.09% of saltwater drowning cases.

In summary, the results of the study show that in the majority of the forensic autopsy reports in cases of drowning, it is not possible to definitively determine which form of overinflation of the lungs is involved. On the other hand, cases with a definitively established hyperaerated/hyperhydremic form do not always correspond to drowning, respectively, in fresh/salt water. However, the changes of the lungs are of essential importance for the diagnostic process of drowning. These data provide grounds for making some recommendations for a more detailed description of the macroscopic characteristics of the overinflation of the lungs, as well as for conducting histological analysis to establish the details of this condition in order to more accurately determine the hyperaerated or hyperhydremic form.

Similar to the lung overinflation, the type of subpleural hemorrhages is also associated with the type of water in which drowning occurred [22, 35]. According to our results, Tardieu's spots were observed in approximately half of saltwater drowning cases, while in freshwater drowning cases, they occurred in only 9.76%. Paltauf's spots were found in 9.09% of saltwater drownings, while in freshwater cases, this percentage was 39.02%. Although both types of subpleural hemorrhages were found in 29.14% of all reviewed cases, the obtained data indicate that Tardieu's spots were more commonly observed in saltwater drowning, while Paltauf's spots were more frequently found in freshwater drowning cases. It should be noted that petechial hemorrhages on the lung surface can also be observed in other types of mechanical asphyxia, as well as in other causes of death [8, 10, 21, 22, 35]. On the other hand, a number of authors consider Paltauf's spots to be a major morphological sign for the diagnosis of drowning [8, 31, 32, 36]. According to a study conducted at the Institute of Forensic Medicine at the Medical University of Greifswald, Germany, Paltauf's spots occur in 18.0% of drowning cases. The results of the present study are significantly close to these values – Paltauf's spots were observed in 17.22% of all drowning cases. Some authors believe that this morphological finding has no significant diagnostic value, and the frequency of finding Paltauf's spots in drowning cases varies widely (from 5 to 60%) [17, 19].

In the present study, Sveshnikov's sign (presence of free fluid in the sphenoidal sinus) was found to be positive in a significant percentage of cases (96.50%). According to literary sources, the positivity of this sign in drowning also varies widely, from 65% to 92% [6, 22, 31, 35]. Some authors note that the presence of fluid in the paranasal cavities may not indicate drowning, as fluid can enter post-mortem during the body's stay in water, and the cause of death may be of another nature [3, 17, 19]. Of particular interest is a study that examined corpses divided into three groups: the first group consisted of freshwater drowning cases without signs of cadaveric decomposition; the second group included corpses with signs of decomposition that were recovered from freshwater bodies; the third group was a control group and included decomposed corpses that died outside an aquatic environment. The results of the study showed that Sveshnikov's sign among the three groups was positive in 79% for the first group, 78% for the second, and 41% for the third group, respectively. These data provide grounds for the authors to conclude that the presence of fluid in the sphenoidal sinus can be considered a vital reaction, but only in cases without advanced putrefaction processes [37].

Fluid from the sphenoidal sinus can be easily aspirated with a syringe and examined for the presence of diatoms and other foreign bodies [3, 22, 35]. In the practice of the Clinic of Forensic Medicine at St. Marina University Hospital, Varna, fluid from the sphenoidal sinus is usually used for diatom analysis, except in cases of advanced cadaveric decomposition, when chemical processing of internal organs, including bone marrow, is performed.

Diatoms are unicellular microorganisms with a siliceous shell that typically inhabit aquatic environments. In drowning, they enter the body along with water through the respiratory system and subsequently spread to other organs via the bloodstream. In forensic medical practice, their detection in the corpse is of significant importance in the process of diagnosing death due to drowning. Typically, diatoms are found in about 70% of drowning cases [21, 13, 22, 28, 35]. According to Yovchev I, diatoms and other foreign bodies were found in 70.85% of cases with a positive Sveshnikov‘s sign, in the fluid taken from the sinus [35]. In another study that examined samples of fluid from the sphenoidal sinus and lung tissue taken from drowned corpses, diatoms were found in 86.2% of cases [15]. The results of the present study also show a significantly frequent detection of diatom forms and other foreign bodies (87.76%). Some authors believe that for diatom analysis to be considered significantly positive, the number of diatoms found in a given sample should be substantial, and their type should be the same as those found in the corresponding water body [3, 8, 22]. The diatom test can be extremely useful in cases of drowning, although there is some controversy among different authors regarding its diagnostic value. According to some authors, diatoms are usually found in high percent of all drowning cases, but their absence does not completely rule out the diagnosis of death due to drowning [9, 14, 22].

In our clinic‘s practice, the examination for diatoms is mainly carried out on a sample taken from the sphenoidal sinus, using direct microscopy. In addition to the presence of diatom forms, the presence of other foreign particles such as grains of sand, amorphous materials, etc. is also taken into account. The positive result of this examination is not analyzed independently, but only in combination with other findings established in the given case, such as the circumstances of death or discovery of the body, autopsy findings, etc. In individual cases, depending on the need for additional evidence, a comparative analysis is also applied between the diatom forms found in the body and those found in the water where the incident likely occurred.

## Conclusion

Although there is a trend towards a decrease of drowning cases, this type of incident continues to be one of the leading causes of death worldwide and therefore a significant problem for public health and forensic medicine. The analysis of the results obtained and the data from the reviewed literature clearly show that there is no single morphological sign that is diagnostically specific only for cases of death resulting from drowning. The frequent detection of foam in the nasal and mouth orifices, as well as along the airways, in cases of drowning, both in the present study and according to the data of a number of studies, emphasizes the significant diagnostic value of this autopsy finding. On the other hand, cyanosis and subconjunctival hemorrhages are not specific for drowning, but their detection together with other findings can also be of significant importance in the diagnostic process. The changes in the lungs analyzed in the present study indicate the need for a more precise description of the morphological findings and the application of additional histological examination in order to determine in detail the form of lung overinflation in cases of drowning and the possible relationship with the type of water in which it occurred (fresh or salt water). Regarding the high percentage of the studied drowning cases in which fluid is found in the sphenoidal sinus, it is advisable to refine some additional details, such as the volume of fluid that is detected. This feature is also of interest for future studies, such as the inclusion of control groups with corpses in different stages of decomposition, who died outside the aquatic environment. Refining the diatom analysis would also help to improve the quality of the diagnostic process in cases of bodies being discovered in the water, but again the results should be commented on in combination with the other findings from the examination of the corpse and the circumstances of the scene.

The results of the present study highlight the need for a comprehensive and detailed assessment of autopsy findings, examinations performed, and all investigation data in cases of body discovery in water with suspected drowning. The data from the present study contribute to expanding knowledge about the frequency and diagnostic value of some of the main morphological changes observed in drowning, which in turn significantly supports daily forensic practice.

## References


1. **Aflanie, I., G. Suharto, P. Nurikhwan.** Postmortem characteristics of drowning death in freshwater: a systematic review. – *Russian Journal of Forensic Medicine*, **10** (2), 2024, 220-228.
2. **Alexander, R., J. Jentzen.** Neck and Scleral Hemorrhage in Drowning. – *Journal of Forensic Sciences*, **56** (2), 2011, 522-525.
3. **Armstrong, E., K. Erskine.** Investigation of Drowning Deaths: A Practical Review. – *Academic Forensic Pathology*, **8** (1), 2018, 8-43.
4. Automatic Diatom Identification and Classificatoin (ADIAC) – Diatom Image Database. Available at: https://websites.rbge.org.uk/ADIAC/db/adiacdb.htm
5. **Betz, P., R. Penning, W. Keil.** The detection of petechial haemorrhages of the conjunctivae in dependency on the postmortem interval. – *Forensic Science International*, **64** (1), 1994, 61-67.
6. **Bohnert, M., D. Ropohl, S. Pollak.** Forensic medicine significance of the fluid content of the sphenoid sinuses. – *Archiv fur Kriminologie*, **209** (5-6), 2002, 158-164. [In German]
7. **Davceva, N., A. Duma.** Differential diagnostic elements in the determination of drowning. – *Romanian Journal of Legal Medicine*, **13** (1), 2005, 22-30.
8. **Dettmeyer, R. B., M. A. Verhoff, H. F. Schütz.** Forensic Medicine: Fundamentals and Perspectives, Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, 243-260.
9. **Di Maio, V., K. Molina.** DiMaio's forensic pathology. Third edition. Boca Raton, FL: CRC Press, 2022, 373-384.
10. **Fn, J., J. Liando, J. Gotama, K. Masreni, K. Christina.** The Challenges of Diagnosing Drowning Death Case. – *IIMJ*, **3** (2), 2022, 108-118.
11. **Girela-Lopez, E., C. M. Beltran-Aroca, H. García-Mozo H.** Diatoms in Forensic Analysis – In: *Modern Trends in Diatom Identification* (Eds. Cristóbal G., Blanco S., Bueno G.). Springer International Publishing, 2020, 239-256.
12. **Hansen, I., A. Thomsen.** Circumstances and autopsy findings in drownings, Department of Forensic Medicine, Aarhus University, 2006-2015. – *Scandinavian Journal of Forensic Science*, **24** (1), 2018, 1-6.
13. **Klevno, V., Y. Chumakova, M. Kislov, O. Popova, S. Dubrova.** New diagnostic signs of drowning based on virtual autopsy results. – *Russian Journal of Forensic Medicine*, **6** (3), 2020, 53–57.
14. **Knight, B., P. J. Saukko.** Knight's Forensic pathology. 3rd ed. London : New York: Arnold, Distributed in the United States of America by Oxford University Press, 2004, 395-411.

15. **Lin, C., W. Yen, H. Hsieh, L. Tsai, T. Huang, C. Huang, Y. Yu, C. Shun, J. Wu, C. Chou, A. Linacre, J. Lee.** Diatomological investigation in sphenoid sinus fluid and lung tissue from cases of suspected drowning. – *Forensic Science International*, **244**, 2014, 111-115.
16. **Lunetta, P., J. H. Modell, A. Sajantila.** What Is the Incidence and Significance of "Dry-Lungs" in Bodies Found in Water? – *American Journal of Forensic Medicine & Pathology*, **25** (4), 2004, 291-301.
17. **Lunetta, P., J. H. Modell.** Macroscopical, Microscopical, and Laboratory Findings in Drowning Victims. – In: *Forensic Pathology Reviews* (Eds. Tsokos M). Totowa, NJ: Humana Press, 2005, 3-77.
18. **Lunetta P., A. Penttilüa, A. Sajantila.** Circumstances and Macropathologic Findings in 1590 Consecutive Cases of Bodies Found in Water. – *The American Journal of Forensic Medicine and Pathology*, **23** (4), 2002, 371–376.
19. **Madea, B.** Asphyxiation, suffocation, and neck pressure deaths. Boca Raton: CRC Press, 2020, 260-284.
20. National Statistical Institute – Mortality by causes, sex and age. Available at https://www.nsi.bg/en/statistical-data/236/765
21. **Nečas, P., P. Hejna.** Eponyms in forensic pathology. – *Forensic Sci. Med. Pathol.*, **8** (4), 2012, 395-401.
22. **Radanov, St.** Forensic medicine and deontology. Sofia: *Siela*, 2006; 192-216. [In Bulgarian]
23. *Radoinova, D., Y. Kolev, E. Kaisheva, M. Baltov.* Forensic medical examination of drownings in the districts of Varna, Gabrovo and Smolyan. – *Society of Water Rescue Specialists* – Varna. 2008, 63-68. [In Bulgarian]
24. **Rao, V., C. Wetli.** The Forensic Significance of Conjunctival Petechiae. – *The American Journal of Forensic Medicine and Pathology*, **9** (1), 1988, 32-34.
25. **Schneppe, S., M. Dokter, B. Bockholdt.** Macromorphological findings in cases of death in water: a critical view on "drowning signs". – *Int. J. Legal Med.*, **135** (1), 2021, 281-291.
26. **Somers, G., D. Chiasson, G. Taylor.** Presence of periorbital and conjunctival petechial hemorrhages in accidental pediatric drowning. – *Forensic Science International*, **175** (2–3), 2008, 198-201.
27. **Szpilman, D., J. Sempsrott, J. Webber, S. C. Hawkins, R. Barcala-Furelos, A. Schmidt, A. Queiroga.** "Dry drowning" and other myths. – *CCJM*, **85** (7), 2018, 529-535.
28. **Tambuzzi, S., G. Gentile, R. Zoia.** Forensic Diatom Analysis: Where Do We Stand and What Are the Latest Diagnostic Advances? – *Diagnostics*, **14** (20), 2024, 2302.
29. **Tasis, M., B. Budakov, D. Draskovic, M. Durendic-Brenesel, A. Oros, V. Pilija, M. Simic, G. Stojiljkovic, B. Susnjar, S. Takac, I. Veselinovic, R. Vukovic, D. Zgonjanin, P. Budakov.** Forensic medicine. Novi Sad: *ZMAS*, 2007, 88-94. [In Serbian]
30. **Van Beeck, E., C. Branche, D. Szpilman, J. Modell.** A new definition of drowning: towards documentation and prevention of a global public health problem. – *Bulletin of the World Health Organization*, **83** (11), 2005, 853-856.
31. **Viter, V., A. Vavilov, V. Kungurova.** Forensic examination of mechanical asphyxia. – *Izhevsk Press*, 2008, 20-29. [In Russian]
32. **Voloshynovych, V., N. Kozan, V. Voloshynovych, J. Kotsyubynska, M. Voloshynovych, G. Zelenchuk, V. Chadiuk.** Current state and prospects of forensic-medical diagnosis of drowning: A review of the literature. – *Problems of Forensic Sciences*, **129**, 2022, 49-73.
33. **Whitwell, H., P. Harvey, A. Kolar, K. Thorne.** Mason's Forensic Medicine and the Law. London: *Bloomsbury Professional*, 2023, 131-144.

**34.** World Health Organization. Drowning, 2024 Available at https://www.who.int/news-room/fact-sheets/detail/drowning

**35. Yovchev, I.** Morphological changes and laboratory diagnostics in drowning in seawater: on expert cadaveric material and on experimental animals. *Varna, Medical University – Varna*, 1974. [In Bulgarian]

**36. Zhulzhik, E.** Diagnostics of drowning in modern forensic medicine. – *Scientific-methodological electronic journal "Koncept"*, **4**, 2015, 191–195. [In Russian]

**37. Zivkovic, V., D. Babic, S. Nikolic.** Svechnikov's sign as an indicator of drowning in immersed bodies changed by decomposition: an autopsy study. – *Forensic Sci. Med. Pathol.,* **9** (2), 2013, 177-183.