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Fatal Diving Accidents in East Germany

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Abstract

Introduction: Whilst often considered a sub-category of drowning, fatal diving accidents prove to have a vastly different pathophysiology that leads to death. The intent of this study was to show whether autoptic findings mirror those differences or contrarily find similarities between fatal diving accidents and classic drowning.

Materials and Methods: Data from the institutes of forensic medicine in Leipzig, Halle and Dresden in the timespan of 2012 to 2022 was used and evaluated using IBM SPSS version 29. We found 374 drowning related deaths, 15 of which were declared diving accidents.

Results: The main cause of death in the evaluated diving accident cases is most often drowning (40%), followed by diving-typical decompression sickness (26,7%). Postmortem computerized tomography scans show intracranial gas embolism in 46,7% of diving cases. Macromorphological drowning sings are found in most fatal diving cases bearing no significant difference to drowning cases.

Conclusions: Though in theory, the pathophysiology of drowning and diving-related death are very different, the forensic reality in autopsy shows overlaps of drowning signs and even cause of death in fatal diving accidents. This may be due to differences in the etiology of fatal diving accidents.

Keywords: Fatal Diving Accidents; Drowning; Diving; Decompression Sickness; Postmortem CT; Macroscopic findings in drowning

Introduction

The diving accident is commonly defined as a potentially life-threatening event caused by decreased environmental pressure while diving [1]. A classic pathological entity in diving accidents is decompression sickness (DCS), which can be subdivided into musculoskeletal symptoms and neurological symptoms. Its cause is the development of nitrogen bubbles when ascending too quickly [2]. A related phenomenon that often is not entirely distinguishable from DCS is the arterial gas embolism caused by barotrauma of the lungs while ascending under insufficient expiration. The gas disseminates in pathological and physiological vessel shunts throughout the body, for example a patent foramen ovale in the heart, which leads to death [1,2].

Although the European Underwater and Baromedical Society and its German associate, the GTÜM (Gesellschaft für Tauch- und Überdruckmedizin), regularly update guidelines [3] on diagnosis and treatment of diving accidents, a central statistic for diving accidents does not yet exist [2]. An attempt is made by the community of German sports divers (Verein Deutscher Sporttaucher), who reported 62 diving and diving-related accidents in 2018 [4]. This is a low number in comparison to classic drowning. According to the German Life Saving Association (DLRG), 378 people died due to drowning in Germany in 2023 [5]. Globally, drowning remains one of the leading causes of unnatural death, especially in children below 15 [6]. Definitions for drowning have varied and changed over the years, however the most recognized aspect is the inhalation of liquid, mostly water, that leads to hypoxia and eventually suffocation [7].

Drowning usually happens in four phases leading to death. First, after submersion the breath is held as to prevent water from entering the airways. However, this state often cannot be held for longer than two minutes due to the accumulation of carbon dioxide in the blood which triggers the brain's respiratory center. Water is subsequently inhaled into the airways and lungs leading to coughing and possible emesis. Obtundation, cerebral seizures and lastly loss of consciousness and terminal apnea follow, leading to cardiac arrest and death [8].

This article includes evaluation of typical macroscopic drowning signs, so in the following they will be clarified briefly.

i. **Foam cone:** A term usually found in opiate intoxication [9] describing foam in the upper airways releasing through the nose and forming a fungus shape, as it is described in German, above the top lip. It is known as the only specific external sign of drowning. The forming of a foam cone is the result of a mixture of alveolar secretion, air, and aspirated water in the process of drowning [10]. This foam then continues into the trachea and lower airways and can be found in autopsy.

ii. **Paltauf's spots:** These petechiae refer to washed out subpleural hemorrhages caused by the destruction of capillaries following massive lung overinflation [8]. Emphysema aquosum: The drowning associated emphysema often appears as a dry lung overinflation. It is caused by water being forced out of the lungs due to high osmotic pressure [8].

iii. **Svechnikov-sign:** This sign describes the autoptical finding of fluid in the sphenoid sinus, which is typically aspirated with a needle. In strongly decayed corpses it can prove difficult to differentiate it from putrefaction fluid [11].

iv. **Wydler-sign:** The Wydler-sign describes a tripartite layering of the stomach contents, most typically into a foamy layer above a layer of liquid above a solid layer [11].

v. **Spleen sign:** A depletion of the spleen, which often presents as a shrunken, dry organ in autopsy is considered a nonspecific sign of drowning or asphyxiation. The exact pathomechanism is not yet understood [12].

vi. **Fritz's mucosal tears:** This sign is characterized by longitudinal lesions in the gastric mucosa which primarily result from repeated vomiting in the second stage of drowning [13].

The purpose of this study is to compare the entities drowning and fatal diving accidents in forensic medicine and find similarities and differences that must be considered when conducting an autopsy.

Materials and Methods

Autopsy transcripts of drowning and fatal diving cases documented between 2012 and 2022 from three East German institutes – Leipzig, Halle and Dresden were reviewed retrospectively. The list of evaluated items can be found in Table 1. Initially, those items were collected in an excel spreadsheet (version 2.7.2) and later converted to an SPSS file (version 29) for statistical evaluation.

Statistically, many results are based on an initial descriptive frequency distribution of most items. T-Tests were used to determine significant differences between the mean values of age and blood / urine alcohol levels with the level of significance being set at α=0,05.

X2 tests including contingency tables were used to analyze correlations between nonparametric variables, for example cause of death in relation to drowning and diving accidents regarding their frequency distribution. All figures were created using SPSS. (Table 1)

Table 1: Evaluated items in this study filtered by sub-category.

Patient-based data	Age [years]	Sex [m/f]		
General forensic data	Cause of death	Mode of death [suicide, accident, homicide, undetermined]	Water body [lake, river, bathtub, sea, pond, swimming pool, other]	State of decay [none, low-grade, high-grade]
Circumstances of death	Found dead, futile CPR[1], ROSC[2]	Survival time [none, minutes, hours, days]	Postmortem interval [hours, days, weeks-months, years]	
Macroscopic findings	External sign: „foam cone“-[positive / negative]	Pulmonary signs: emphysema aquosum, foam in lower airways/lungs, Paltauf-spots [positive/negative]	Extrapulmonary signs: Svechnikov-sign, Wydler-sign, condition of spleen, Fritz-sign, intramuscular hemorrhage in back muscles [positive/negative]	
Additional findings	Postmortem CT[3] [gas embolus/other]	Histology [specific drowning lung/ unspecific]	Blood- and urine alcohol levels [‰]	Toxicology [none, (sub)-therapeutic dose, over-therapeutic dose, toxic dose, lethal dose]
[1] CPR = cardiopulmonary resuscitation				
[2] ROSC = return of spontaneous circulation				
[3] CT = computed tomography scan				

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Results

In total, we reviewed 332 autopsy cases of drowning and 15 fatal diving accidents between 2012 and 2022. 80% of the diving cases were male and 20% female. In drowning cases, 64,8% were male and 35,2% female. The average age of fatal diving cases was 49,4 years for men, 44,3 years for women and 48,4 years in total. Although there was not a significant difference in age between gender in diving accidents, there was one in drowning cases. The average age of women at 55,2 years and of men at 47,3 years showed a statistically significant difference (p=0,003) meaning that women die in higher age. The overall age average for drowning accidents was 50,1 years. However, the average ages of both drowning and fatal diving accidents are very similar (Figure 1).

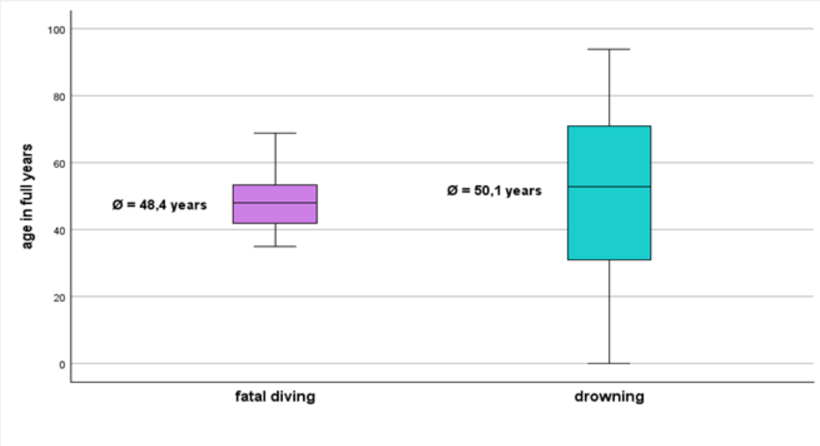

Figure 1: Age distribution and average age of drowning and fatal diving cases in years.

73,3% of divers were found in a lake, the other 26,7% were listed under the category "other", which most commonly describes the likes of water filled mine shafts or gravel pits. In comparison, 32,7% of all drowning victims were found in rivers, with lakes coming in second at 21,8%. 16,4% were found in bathtubs, 15,2% in ponds, 7% in swimming pools and only 0,9% in bodies of salt water (e.g. the Baltic Sea). 6,1% of cases here were listed under the category "other", which in this case mostly described water filled mine shafts, gravel pits or even rain barrels.

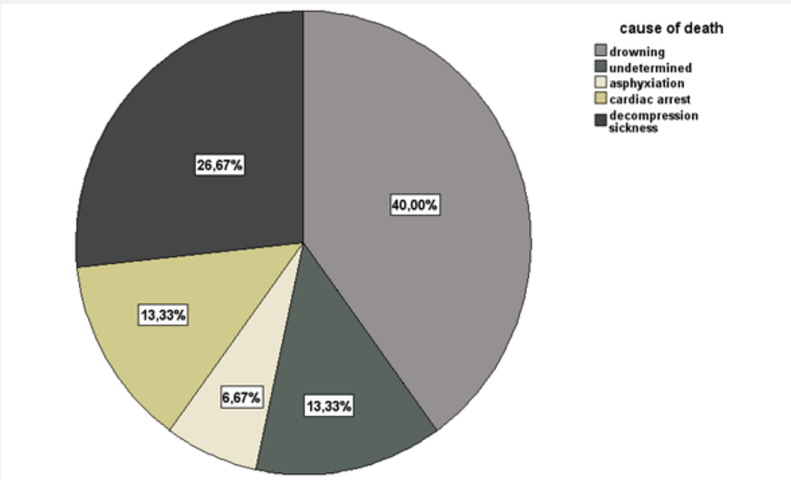

Figure 2: Percentual distribution of cause of death in fatal diving accidents.

40% of fatal diving accidents were forensically labelled as death by drowning, followed by 26,7% in which DCS was named as cause of death. Comparatively, 67,8% of all drowning fatalities were labelled as such as well.

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Other causes of death in drowning cases include asphyxiation or hypoxic brain death, though in nearly 17% of those cases a cause of death could not be determined. A diving-typical cause of death such as DCS was not found in drowning cases. A statistically significant difference between the cause of death “drowning” in diving accidents and drowning was found at a p-value of 0,26 in favor of the drowning cases. It should however be noted that the vast gap in case numbers might be of influence here (Figure 2).

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Different from the cause of death, the mode of death describes the assumed circumstances under which death took place [14]. In the institute of forensic medicine in Leipzig, the mode of (presumably) unnatural death is divided into suicide, accident, homicide and undetermined. 14 of 15 diving fatalities were labelled as accidents. One of them remained undetermined. The main mode of death for drowning accidents was also accidents at 40,7%, closely followed by an undetermined mode of death at 36,1% and suicide at 19,9%. Homicides labelled as drowning were rare and only scored 0,9%.

If we compare the state of decay, 73,3% of all fatal diving accidents showed no decay at all, with 13,3% showing low-grade decay or high-grade decay. In drowning victims, 50,5% showed no decay, 19,9% showed low-grade decay and 29,6% showed high-grade decay. A significant difference between the state of decay in drowning and diving fatalities could not be found. The postmortem interval in diving accidents was mere minutes in 66,7% of cases. However, one case was first found several years after death. In drowning cases, the postmortem interval is most commonly hours at 38,5% and days at 31,4%. 19,9% of cases were found within minutes and 10,2% after weeks to months. Defining the post mortem interval as short (<24h) and long (>24h), a significant difference between diving and drowning cases can be found (p=0,029) in favour of diving accidents showing a much shorter time after death before they were found.

Of all fatal diving accidents, only one could be revived to the point of ROSC whose total survival time was under 24 hours. 40% received futile CPR. The other 53,3% were retrieved already dead. In drowning cases, 77,7% were found dead, 15,1% received futile CPR and 7,2% and 7,2% were revived until ROSC. Of those with ROSC, 70,8% had an overall survival time of >24 hours with 29,2% surviving less than 24 hours. Looking at macroscopic findings typical for drowning in fatal diving accidents, 40% showed a foam cone. Foam in the lower airways and lungs was described in 60% of cases, an emphysema aquosum in 66,7%, *Paltauf's* spots and *Svechnikov*'s sign in 73,3%, the *Wydler*-sign in 13,3%, the *Fritz*-sign in 6,7%, a depleted spleen in 26,7%.

In drowning cases, 22% showed a foam cone, 38,6% showed foam in the lower airways and lungs, 79,2% showed an emphysema aquosum, 48,5% showed *Paltauf*'s spots, 29,8% a *Wydler*-sign, 5,7% a *Fritz*-sign, 37,3% a depleted spleen and 58,1% a positive *Svechnikov*-sign. A significant difference in the occurrence of macroscopic drowning signs could not be found between fatal diving accidents and drowning cases.

Moving on to additional diagnostics, a histological report was found in 80% of all diving cases, 75% of which showed a so-called drowning lung, which is usually defined by alveolar edema in different stages as well as septal ruptures [15,16]. In drowning, a histology report was made in 38,6%. Of those, 87,5% showed a drowning-lung as described by Reh. A statistic difference between the findings of a drowning lung in histological examination could not be found. A postmortem CT scan was done in 80% of all diving cases. Of those, 46,7% showed intracranial gas embolism and one case showed gas embolism in the aorta among other organs. In drowning, only 8,1% of cases received a postmortem CT. Of those, most showed polytrauma or brain edema. Not one case showed arterial gas embolism.

Toxicology reports showed no significant findings in 73,3% of all diving cases. In 20% a (sub)-therapeutic dose of medication was found and in one case, a toxicology report was not made. Most common substances to be found in all cases including drowning were antidepressants of any kind, Z-drugs and betablockers. Comparatively, 14,5% of all drowning cases did not receive a toxicology report. Of the remaining cases, 57% of reports showed no significant substances. (Sub)-therapeutic dose was found in 27,5%, toxic dose in 12,7% and lethal dose in 2,8% of cases.

An additional toxicologic finding which was viewed separately for this paper is the blood and urine alcohol values. In 93,3% of all diving accidents, a blood alcohol value was tested for and in 66,7% of cases a urine alcohol value was tested for as well. Of those, 46,7% tested positive for both blood and urine alcohol. The average value of blood alcohol is 0,40‰, that of urine alcohol is 0,034‰. In drowning cases, 63,8% tested positive for alcohol in the blood stream and 37% tested positive for alcohol in urine. The average blood alcohol value is 0,74‰, while the average urine alcohol value is 1,06‰. The average values of both blood alcohol (p=0,0014) and urine alcohol (p=0,038) are significantly different, which means the average value of both blood and urine alcohol levels is higher in drowning cases.

Discussion

First and foremost, the difference in case numbers between drowning and diving cases is staggering and might be of influence in some, if not all the evaluated factors. Therefore, these results should not just be taken at face value. Still, they might offer insights to what differences and similarities occur between diving and drowning cases in forensic medicine, especially autopsy. The gender and age distribution of diving and drowning cases were relatively similar, as in more men drowned and died because of a diving accident at an average age around 50 years. The fact that most divers were found in lakes is unsurprising, specifically for the region of Leipzig which is surrounded by lakes which are popular for watersports including diving. The same can be said for drowning, where lakes came in second. Rivers were more

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common for drowning, likely because of the inclusion of two other cities (Dresden, Halle) which are both atop a big river. Naturally, in middle to east Germany, we did not expect to find many cases of drowning or diving in salt water, such as the ocean. The few cases of drowning that were found, were transferred to Leipzig from the Baltic Sea.

Although 40% of diving accidents were labelled as death by drowning, there was a statistically significant difference showing that actual drowning cases are more often labelled as such in reference to the main cause of death. This means that although diving cases share similarities with drowning and the pathophysiology of drowning factors into fatal diving accidents, they are not to be seen as the same forensic entity. 26,7% of all diving cases labelled DCS as cause of death, which never occurred in drowning cases, which makes sense, regarding the fact that DCS alongside arterial gas embolism is a pathophysiology described only for diving as the result of changes in pressure which do not happen during regular swimming that often leads to drowning. Of course, the amount of drowning cases in comparison to diving cases likely does not accurately represent the reality of diving and drowning in forensic medicine. A possible reason for the state of decay in both drowning and diving accidents could be the rule of Casper. It describes the speed ratio of decay in air, water and underground at 8:2:1, which means that corpses in water generally decay at half the speed as those in air [17].

The reason for diving accidents showing a significantly shorter postmortem interval could be the mere circumstance, that usually, dives are not gone on alone, so with a team or group of people around to help the divers when in danger, naturally they do not stay in it very long. The group of drowning accidents however is very heterogeneous with most cases dying out of from people's sight.

Although the postmortem interval in diving accidents was significantly lower, only one case could be revived to the point of ROSC. A reason for this might be the pathophysiology of diving. There are two, sometimes three types of DCS which are classified by severity. DCS I is typically known as mild, whereas DCS II and III correlate to arterial gas embolism and overall, DCS II is described to be more common, whilst isolated arterial gas embolism is rarest [18]. In case studies, it is described that severe arterial gas embolism is never found in surviving patients [19]. This is supported by our data, which showed arterial gas embolism in the brain in 46,7% of cases. These findings may be the result of insufficient or ineffective CPR, a longer than recommended no-flow time or simply the depth of the dive, though most of these factors could not precisely found in our data.

The amount of positive macroscopic drowning signs in fatal diving accidents show no significant difference to those in drowning cases. This means that although the pathophysiology of diving with DCS and arterial gas embolism differs from that of drowning, which is mainly described by asphyxiation in water, the body reacts similarly and therefore shows these signs. Whether those macroscopic findings were the reason that 40% of diving accidents were ruled as drowning in their main cause of death or it was the other way around, is not clear.

Equivalently, this can be seen in the results of histological examination, where 75% of diving cases still showed signs of a microscopic drowning lung. It was not always stated which stages those results were in, so it is inconclusive whether they showed the full signs of a drowning lung correlating to Reh's stage IV or just singular signs correlating to lower stages of drowning lung. Intracranial gas embolism via CT can only be found in cases of fatal diving accidents. This shows, that at least for severe cases of DCS which are linked with arterial gas embolism, CT is a method to differentiate the two if autopsy can't. However, previous studies have also shown that postmortem CT scans cannot really distinguish between drowning and other causes of asphyxiation [20] which has to be kept in mind.

The toxicology findings could be explained by the different circumstances under which diving accidents happen as opposed to classic drowning. Diving is a sport and often done in teams. Professional divers must be cleared by before allowed to go on dives. An arbitrary intoxication would naturally threaten their diving license [21]. However, therapeutic and subtherapeutic doses of medication being found in correlation to the average age of 48 years, it is highly possible that this refers to standard medication used to treat the aging person. This also reflects in the significant difference in blood and urine alcohol levels between diving and drowning cases, although it is surprising to see that 46,7% of divers still tested positive for alcohol at all.

In conclusion, diving accidents share a great amount of forensic similarities with classic drowning cases. The difference in pathophysiology reflects mostly on postmortem CT findings, which may prove as a medium to differentiate the two in the future – especially considering how few of drowning cases usually receive a postmortem CT scan. Autoptic findings in fatal diving accidents might also help further predict which stages of DCS are still survivable and which are moribund, as all the DCS cases we evaluated already showed severe arterial gas embolism in vital organs.

Statements and Declarations

No funding was received for conducting this study. The authors have no competing interests to declare that are relevant to the content of this article. The study complies with the current laws of the country in which the research was performed and with institutional regulations.

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