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Pleural effusion in bodies recovered from water

[Sudan çıkartılan cesetlerde plevral effüzyon]

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Abstract

Both in saltwater and freshwater drowning cases, a common autopsy sign is pleural effusion. However, the factors that determine the amount of pleural effusion have not been well established. An attempt was therefore made to correlate the amount of pleural fluid in bodies recovered from water with several parameters registered on the judicial files as well as autopsy findings from the years 1994–1998. The number of cases with pleural fluid increase was found to be very high in saltwater drowning (P <0 001). But, when the freshwater and saltwater drowning cases with pleural fluid increase were compared according to pleural fluid amount, no significant difference was detected (521 ± 340 and 768 ± 536 ml, respectively). Although there was a positive correlation between the decomposition degree and the fluid in the pleural cavity, a relative decrease was detected in the amount of effusion contrary to the expectations in cases of extreme decomposition. Pleural fluid amount provides significant data about the type of water and the cause of death in early postmortem interval. And there is a link between the time spent in water and the amount of pleural effusion. With the advance of the postmortem interval, decomposition level and the duration of immersion should be taken into account in differential diagnosis.

Keywords:

Drowning; pleural effusion; decomposition.

Özet

Gerek tuzlu gerekse tatlı suda boğulmanın yaygın otopsi bulgusu plevral effüzyondur. Keza plevral effüzyon miktarının tanımlanmasına yönelik faktörler henüz iyi belirlenmemiştir.Böylece, 1994-1998 arasında sudan çıkarılan cesetlerdeki otopsi bulguları ve yargıya yönelik parametreler ile plevral sıvı miktarı arasında bir ilişki kurulma teşebbüsünde bulunuldu. Plevral sıvı bulunan olguların sayısındaki artış, tuzlu suda boğulanlar arasında çok yüksekti (p<0.001). Ancak, plevral sıvı bulunan tuzlu ve tatlı suda boğulma olgularındaki plevral sıvı miktarları karşılaştırıldığında, anlamlı bir fark bulunmadı (521 ± 340 and 768 ± 536 ml, sırasıyla). Mamafih, plevral boşluktaki sıvı ve çürüme derecesi arasında pozitif bir ilişki vardı. Beklenen aksine aşırı çürümüş olgularda, effüzyon miktarı göreceli olarak azalmaktaydı. Plevral sıvı miktarı, suyun tipi ve erken postmortem dönemde ölüm sebebi hakkında önemli bir veri sağlar. Ve suda geçen zaman ve plevral effüzyon miktarı arasında bir bağlantı vardır. Postmortem dönemin ilerlemesi ile, çürüme seviyesi ve su altında kalma süresi ayırıcı tanıda dikkate alınmalıdır.

Anahtar Kelimeler:

Suda boğulma, plevral effüzyon, çürüme.

1. Introduction

Death by drowning is a major worldwide cause of unnatural death, being a social problem with judicial reflections [1]. It is reported that about 140 000 deaths by drowning take place per year all over world [2]. In Istanbul with its 10 million inhabitants, 9% of about yearly 2500 autopsies were drowning cases [3]. This gives rise to problems in the evaluation of the cases. In many cases, the diagnosis can be made from autopsy findings as well as complementary tests. However, there are no absolutely specific methods of establishing the diagnosis of drowning, which may be one of the most complex diagnoses in forensic medicine [1,2,4–7]. Increase in pleural fluid is frequently encountered and is a significant sign for drowning together with lung weight [8]. It is reported that there is a correlation between the increase of pleural fluid and the duration of immersion and post-mortem interval [3,7–9]. However, this correlation has not been well established. Large amounts of pleural fluid can be found even after a short time spent in water, whereas a body can be recovered from water after weeks without an increased amount of pleural fluid [9]. The present study aimed to investigate the factors affecting the amount of pleural effusion in bodies recovered from water. Data obtained from judicial files, the autopsy and the laboratory analysis were evaluated.

2. Material and methods

537 cases suspected of drowning recovered from water were evaluated in the Department of Forensic Medicine, Cerrahpasa Medical Faculty, Istanbul University between 1994 and 1998. Cases in which the immersion medium had gained direct access to the chest cavity, e.g. trauma or decomposition, were excluded. In addition cases in which the pleural cavities are closed by adhesion were excluded since the effusion does not occur. Also those under 18 years old were not included in the study since the data comparisons of individuals under 18 years old and adults would not be convenient.

The cases were divided into three main groups according to the death causes recorded in autopsy reports; non-drowning (Group A), drowning (Group B) and undetermined (Group C). The diagnosis of drowning (leading to the classification in group B) was based on the presence of anatomico-pathologic findings, such as over inflated lungs, emphysema aquosum, frothy contents in the airways, diatoms in parenchymatous organs (other than the lungs) and bone marrow, fluid content in the gastrointestinal system, intercostal hemorrhage, middle ear congestion and hemorrhage, bloody watery fluid in the sinuses and scene investigation reports. Furthermore other possible causes of death, such as intoxication and trauma are ruled out before diagnosis of drowning is concluded in autopsy reports.

On the other hand, the cases were divided into four subgroups according to the severity of the decomposition findings; those without decomposition findings (I), those with early decomposition signs (II), those with advanced decomposition signs (III) and those with late period decomposition findings accompanied by tissue loss (IV). Further-more the relationship between decomposition and duration of immersion was assessed with regard to the monthly average water and air temperature in Istanbul by using the cases with clearly known duration of immersion. External postmortem findings versus duration of immersion are shown in Table 1 with respect to the average seasonal temperature.

There were 43 cases in-group B with pleural fluid increase and known duration of immersion. The correlation between the duration of immersion and the amount of pleural fluid was investigated in these cases. Also the duration of immersion for each case using Table 1 was estimated taking into account such factors like air and water temperatures and type of water. Then the correlation between the duration of immersion and the amount of pleural fluid was investigated for group B cases with pleural fluid increase.

Table 1. *External findings in relation to duration of immersion with respect to seasonal temperature in Istanbul*

Level of decomposition	External findings	Winter water temperature: 4–7 °C, air temperature: 4–9 °C (minimum–maximum)	Summer water temperature: 18–22 °C, air temperature: 20–30 °C (minimum–maximum)
I	Skin maceration (-)	<8–10 h	<3–6 h
II	Skin maceration (+)	<48 h	<24 h
	Early decomposition	4–10 days	36–72 h
III	Peeling of epidermis on hands and feet	3–4 weeks	1–2 weeks
IV	Muscle loss with skeletal exposure	6–10 weeks	4–6 weeks

The following parameters were recorded and used for statistical analysis: age, body weight, gender, the period between the recovery of the body and the autopsy, duration of immersion, level of decomposition, type of water, the season to reflect the water temperature, amount of pleural effusion, lung weights, the number of diatoms detected in the lung and blood alcohol levels. Diatom examinations were performed with the routine nitric acid method. The cases, in which 40 ml or more fluid accumulation in each pleural cavity which amount to a total of 80 ml or more, were considered to have increased pleural fluid.

The weight and the height of the body were measured by the mortuary technicians but were supervised by the forensic medicine specialist or forensic pathologist responsible for the autopsy. All the bodies were weighed naked with the same electronic weighing machine (HANA of type 3000P). The right and left lungs were weighed separately before being dissected and cut open. Weighing machines with mechanic pointers used were of the same type (NMK10/ 11265, 0–10 000 g range, 5 g intervals) and certified by the TSE (Institution of Turkish Standards). They were daily calibrated with a reference weight of 0.5 kg.

Statistical analysis was performed by means of SPSS for Windows 7.5 version program. One-way ANOVA was used for statistical significance among groups. Also, x2 and Spearman's correlation tests were utilized to compare the parameters in groups.

3. Results

Of 271 cases included in the study with decomposition levels I and II; 17 were determined to be non-drowning cases like manual or ligature strangulation, smothering, stab wounds, and intoxication (Group A); 192 were determined to be drowning (Group B); and death causes of 62 could not be determined in spite of detailed investigations (Group C). In all groups, the amount of pleural fluid did not have significant difference according to gender, age, body weight and cause of death. And there was no correlation between body weight and total lung weight. A significant difference was found between total lung weights of cases in groups A, B and C (P <0...001, Table 2). Also as proposed by many investigators as a principal criterion for drowning, if the total lung weight of 1000 g is accepted as cutoff weight, a significant difference was found between the groups (P <0.01, Fig. 1). On the other hand no difference was found between the lung weights of fresh and saltwater drowning cases.

Table 2: *Total lung weights and pleural fluid amount according to death cause*

Cause of death	Lung weight (g) ¹	Pleural fluid (ml) ²
Nondrowning (A)	1016± 276	90 ±14
Drowning (B)	1360± 396	705± 502
Undetermined (C)	1096 ±345	620± 373

*[(¹) Mean S.D., there were significant differences in cases with decomposition levels I and II by ANOVA (P <0.001) (*²) Mean S.D., there were no significant differences in cases with decomposition levels I–II and the increased pleural fluid by ANOVA]*

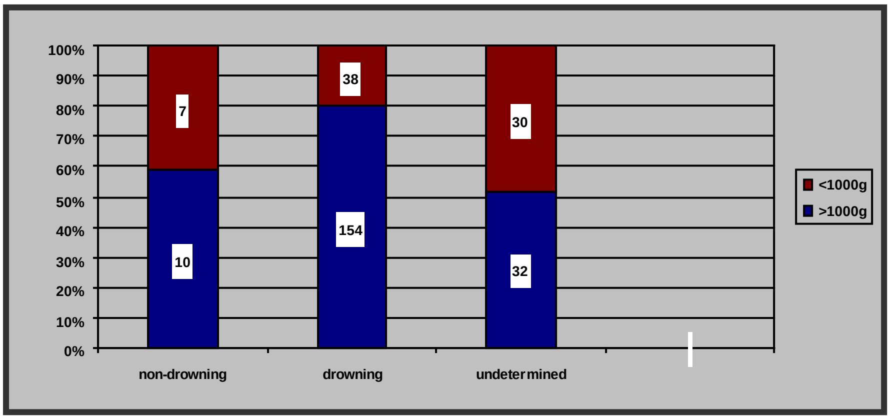

Fig. 1. *The distribution of the percentage and number of cases according to death cause when accepted as a reference lung weight: 1000 g.*

In-group B, 120 saltwater and 72 freshwater drowning cases were detected. In cases with decomposition levels I and II, the pleural fluid increased in 80 of saltwater drowning (66.6%) and only in 22 of freshwater drowning cases (30.5%, Table 3). When the fresh and saltwater drowning cases were compared according to the presence of pleural fluid increase, there was a significant difference. The number of cases with pleural fluid increase was found to be very high in saltwater drowning (P <0.001). But, when the freshwater and saltwater drowning cases with pleural fluid increase were compared according to pleural fluid amount, no significant difference was detected (521±340 and 768 ±536 ml, respectively). Accordingly, the material was divided into those with and without increased pleural fluid; no significant differences were found between these two groups with regard to gender, age, total lung weights and the effect of alcohol. Average lung weights in groups with and without pleural fluid increase were 1326 436 and 1310 358 g, respectively. In the group with pleural fluid increase, there was no significant correlation between total lung weights and pleural fluid amount.

Table 3: The distribution of 207 cases with pleural fluid increase according to decomposition level

Level of decomposition	Fresh water			Salt water		
	Non-drowning	Drowning	Undetermined	Non-drowning	Drowning	Undetermined
I	-	13	3	-	49	12
II	3	9	2	1	31	6
III	-	5	1	2	47	5
IV	1	-	-	-	8	9
Total n	4	27	6	3	135	32

We did not find a correlation between pleural fluid amount and number of diatoms detected in the lungs. In-group B, 40 cases were determined to have blood alcohol levels ranging from 30 to 380 mg/dl, and no relationship between blood alcohol level and pleural fluid amount was detected. The average pleural effusion amount in cases recovered in winter was found to be higher than those recovered in other seasons in group B (P <0.05, Fig. 2). But, the number of cases with pleural fluid increase was found to be higher (79%) in summer (P <0.05). Similar traits were seen in Group C as well, but they were not found to be statistically significant.

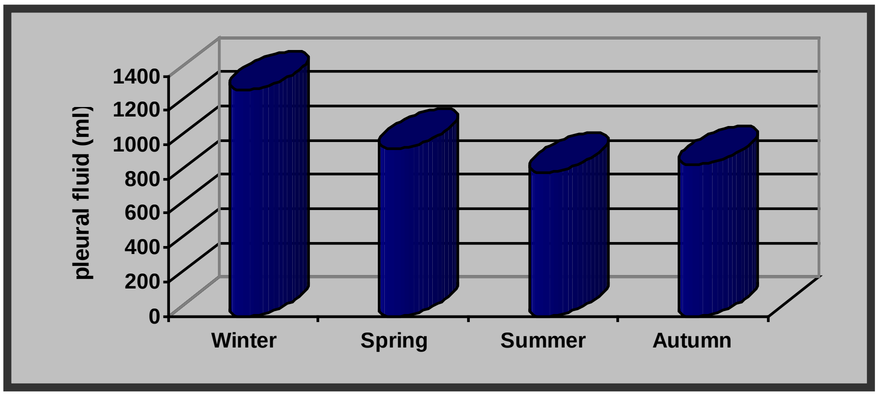

***Fig. 2.** The relationship between seasonal changes and amount of pleural fluid in drowning cases. There were significant differences between winter and other groups. P<0.05*

In all groups no significant relationship between the pleural fluid amount and the time elapse from recovery to autopsy (range 4–96 h) was observed (r= -0.122, P >0.05). However, 43 cases in-group B with pleural fluid increase and of whose exact durations of immersion known, a significant positive correlation between the duration of immersion and the amount of pleural fluid was found (r=0,54, P <0.01). Also significant but weak correlation was found between the estimated immersion periods and amount of pleural fluid in all Group B cases with pleural fluid increase (r=0.32, P <0.01). Also there was a significant relationship between decomposition level and pleural fluid amount in all groups (r=0.46, P <0.001). In level IV of the decomposition, the fluid in the pleural cavity was tend to decrease (Fig. 3.).

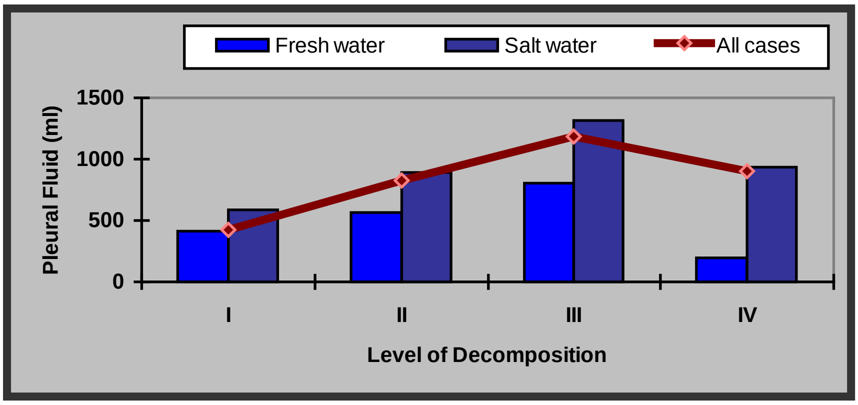

***Fig. 3.** The relationship between decomposition and amount of pleural fluid in the cases with pleural fluid increase.*

(*) There was a significant relationship between decomposition and pleural fluid amount in these cases. r=0.46, P<0.001

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4. Discussion

Significant increase in lung weight is a very common macroscopic phenomenon in drowning [7,8,10,11]. In this study, average total lung weights were found to be significantly different between the groups divided according to death cause (P <0.001, Table 2). In other studies, it was reported that total lung weights were found to be above 1000 g in a considerable number of drowning cases [8,9,12]. Such a rigid cutoff value might be diagnostically misleading because of the existence of many reasons that might affect the lung weight. But, when the total lung weight of 1000 g is accepted as a reference there was a significant difference between the groups (P <0...01). In a small number of drowning cases (n= 38, 19.7%) lung weights did not have such an increase (Fig. 1). The significant difference of lung weights detected between Groups A and B is an important finding because the comparison is made between the non-drowning immersion cases and drowning cases [8,12].

In most of the cases in-group C the diagnosis of drowning could not be established due to inadequate fluid aspiration and lack of circumstantial evidence suggestive of drowning. Also the presence of alcohol or narcotic substance consumption, findings suggestive of cardiac failure (hypertrophy, scarring, etc.) and nonfatal traumatic findings were found significantly higher in Group C compared to Group B in a former study on the factors restricting the fluid aspiration [13]. In the same study, the internal organs did not contain an adequate number of diatoms diagnostic of fluid aspiration in most of the cases. It is evident that group C contains cases of natural death in water which cannot be confirmed as such. Thus, the inability of differentiation between drowning cases and natural deaths [1] in this group does not permit any conclusions about the origin of the pleural fluid. Pleural fluid amount detected in-group C was comparatively low, however, there was no significant difference (Table 2). These findings suggest that there is a correlation between the amount of fluid aspiration and pleural effusion. The crucial point is that the marked increase in pleural effusion together with other findings supports the diagnosis of drowning.

In drowning cases, the type of water alters the findings. Saltwater is hyperosmolar and leads to plasma leaking out of the capillaries into the alveolar space. Whereas in freshwater drowning, water leaks into the capillaries and causes hemodilution. In this mechanism, it is supposed that the fluid accumulated in alveoli later passes to the pleural cavity by passive leakage. So the amount of fluid in the pleural cavity depends on the water type [2,6,7,14]. In this study, it was observed that the numbers of cases with pleural fluid increase were found to be very high in saltwater drowning (P <0.01). Although the amount of pleural fluid detected in saltwater drowning was comparatively high, there was no statistical difference. There was also no difference between fresh and saltwater drowning cases with respect to the lung weights. And no difference was detected between the cases with and without pleural fluid increase with respect to lung weights. But, in contrary to Kringsholm's et al. [8] suggestion about relative decrease of lung weight due to the increase of the pleural fluid, no correlation was found between total lung weight and the pleural fluid amount in the present study. Morild [9] also found that there was no correlation between the lung weight and the pleural fluid amount. These findings suggest that the postmortem fluid influx into the alveoli due to the hydrostatic pressure difference should be taken into consideration as well as exogenous water inhaled into the lungs during drowning or the endogenous water of the neurogenic pulmonary edema [7,9,15,16]. The postmortem fluid influx might explain the lack of negative correlation between the lung weights and the amount of pleural fluid.

There was no correlation between the number of diatom detected in the lung and the amount of pleural fluid in Group B. This finding was not surprising since the variations in the diatom number of the organs depend upon many factors especially the diatom density in the water [15,17]. The total diatom density tends to be low in May and September (156± 898 and 182± 528 cells/l, respectively) and high in August and November (450± 000 and 1170 ±164 cells/l, respectively) in Istanbul, Bosporus. Also in a study per-formed in our department about the efficiency of diatom analysis in drowning cases it was found that false negative cases were high in September [3,18]. We also evaluated the plankton flora in the pleural fluid in most cases. Nitric acid destroys almost all plankton but some diatoms. Therefore, the pleural fluid reflects the plankton content of the immersion medium more accurately as nitric acid is not used in pleural fluid analysis. Further detailed quantitative, qualitative and morphometric evaluations of diatoms in pleural fluid would be useful in interpreting the source of the pleural fluid correctly. It was expected that a high degree of blood alcohol level would lead to a decrease in the amount of pleural fluid, because alcohol enhances mechanisms, such as vagal cardio-depressive reactions with subsequent decrease of the fluid inhalation into the alveoli [3,7,13,14,19]. However, there was no correlation between blood alcohol level and amount of pleural fluid, a finding consistent with Morild's study [9]. There was also no difference in alcohol level between the groups with and without pleural fluid increase.

A slight increase in the pleural fluid amount was present in Group A except one case. The case was recovered from salt water with decomposition level III (Tables 2 and 3) containing 800 ml of pleural fluid with 2 weeks of immersion period, had been strangulated by a ligature and there were findings like lung weight increase due to asphyxia. The amount of pleural fluid detected in this case might be affected by the edema that caused an increase in the lung weight [9] and postmortem fluid influx. Fluid accumulation in the pleural cavity could be detected in all the immersion cases and therefore the amount of the fluid and duration of immersion is crucial in differential diagnosis [7,16,20].

The seasonal variations in average pleural fluid amount indicate that water temperature affects the pleural fluid amount ($P < 0.05$, Fig. 2). The data was obtained from the Istanbul University, Faculty of Fisheries and Turkish State Meteorogical Service regarding the monthly average air and water temperatures within Istanbul relevant to the years the study was performed [18]. The increase of the pleural fluid amount in winter might be due to excessive fluid aspiration or prolonged immersion time [2,8,9,13]. Cold water accelerates the process of death [8,10]. Therefore, the presence of increased pleural fluid amount does not seem to arise from the increased amount of fluid aspiration. The bodies appear and float relatively late in winter since they decompose late in cold water. In other words, the pleural fluid increase seems to be related to the duration of immersion. In summer, the impact of hypothermia might be ignored and the drowning process is not likely to be interrupted [7,8,10,21]. The condition could explain for the higher percentage of cases with increased pleural fluid in summer. Morild [9] stated that there was no significant correlation between the water temperature and the presence of pleural fluid. In order to avoid the uncertainties referred to by Morild about the exact spot temperature, the appreciation of seasonal atmospheric conditions affecting the water temperature enabled us to make a differentiation between summer and winter because of the 20–25 ºC air temperature difference in Istanbul.

The number of cases with known immersion depth was low. There are some shortcomings in this issue in Istanbul. The number of scene investigation teams trained in this field is not adequate. Therefore, in most of the cases information about the duration of immersion and depth of submersion were not noted. Besides this, the powerful currents in Bosphorus cause the body to be recovered at sites distant from the site of drowning. Therefore the information regarding the drowning site does not give sufficient clues to the depth of submersion. It was evident that the bodies recovered from shallow sites presented either no or only a small increase of pleural fluid. But the low number of the cases allowed no statistical analysis. The time interval between recovery and autopsy, ranging from 4 to 96 h, was also taken into account if it has a significant influence on the amount of pleural fluid. There was no relationship between the interval of 4–96 h and the amount of pleural fluid. This suggests that the changes within this recovery interval do not play a significant role in the amount of fluid detected. But, the correlation between the duration of immersion and amount of pleural fluid suggests postmortem fluid influx into the alveoli. It also indicates the importance of the changes in this period for the amount of fluid detected. On the other hand, in cases with pleural fluid increase, pleural fluid amount increased with advancing decomposition levels but showed a decrease in late decomposition level. In advancing post-mortem intervals, a differentiation of the fluid detected in the pleural cavity from the decomposition fluid is of importance [2,3,7,9,14]. It is based on the quantity, and the amounts over 250 ml are accepted in favor of drowning [7,20,22].As clearly seen in Fig. 3, average amounts showed approximately 400 ml excess between the decomposition levels II and III. Another striking finding was that a decrease happened in advanced stages of decomposition in a similar manner as the increase took place in the former phase. This was also emphasized in the paper of Terazawa where he criticized the study of Morild on pleural effusion [20]. In advanced decomposition, it may be assumed that pleural fluid may diffuse to the surrounding medium (Fig. 3).

Consequently, it should be accepted that the finding of pleural fluid provides significant data about the type of water and the cause of death under certain circumstances. And there is a link between the time spent in water after immersion and the amount of pleural effusion. Therefore, in advanced postmortem interval, changes due to the decomposition mentioned above together with the duration of immersion must be taken into account in the differential diagnosis of drowning.

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