ORIGINAL ARTICLE

Evaluation of the fire-related deaths: Autopsy study

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ABSTRACT

BACKGROUND: The fire is a public health problem that occurs because of various reasons, threatens the lives of organisms, and may cause economic losses. The forensic investigation and the crime (event) scene investigation and first medical examination to be performed for the persons in the fire scene might reveal important evidences.

METHODS: The autopsy reports prepared in Trabzon Branch Office, The Ministry of Justice Council of Forensic Medicine, for the death cases found in fire scene between 2007 and 2016 were retrospectively examined.

RESULTS: As a result of analyzing the 10-year archive data, it was determined that 100 (63.3%) of 158 cases, which have been found in the fire scene and undergone forensic autopsy, were male and 58 (36.7%) were female. By excluding the group of cases with undetected origin, it was determined that there was a statistically significant difference between the homicide-caused deaths and the deaths with other causes (accident and suicide) in terms of the carboxyhemoglobin (HbCO) levels. By grouping the fire scene as outdoor and indoor areas, the comparison made between the HbCO levels of cases is presented in table. The difference between the two groups was found to be statistically significant ($p<0.05$).

CONCLUSION: Starting from the crime scene investigation, a detailed radiological, toxicological, and pathological investigation must be performed for the persons taken out from the fire scenes. It was observed that the HbCO levels can be used in determining the space in which death occurred, the origin, and the comorbidities of the individual.

Keywords: Autopsy; burn; carboxyhemoglobin levels; death; forensic medicine.

INTRODUCTION

Fire is a public health problem that occurs because of various reasons, threatens the lives of organisms, and may cause economic losses. It is known that approximately 300,000 individuals loss their lives because of fire-related injuries every year.[1] It was reported that the burns that are among the most frequently occurring traumatic events are observed mainly among the low- and middle-income countries and the origin is the accident at most.[2] Examining the occurrence mechanism, it can be seen that the burns occur because of thermal, chemical, or radiation factors or electric current.[3]

The forensic investigation and the crime (event) scene investigation and first medical examination to be performed for the persons in the fire scene might reveal important evidences. For the events originating from the murder, contrary to the reasons such as accident and homicide, it was reported that one of the main purposes of the perpetrator might be to hide the events.[4] For this reason, one of the most important aspects is to investigate if the death of an individual, whose body has been taken out from the fire scene, has occurred before or after the fire.[5] It was emphasized that the most important vitality-related evidence in the medical examination is the carbon residuals in respiratory and gastrointestinal

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structures and the elevated carboxyhemoglobin (HbCO) levels in the blood.[6] It was reported that the HbCO concentrations between 5% and 10% might aggravate the disorders in the cardiovascular system, that the HbCO concentrations between 15% and 25% generally cause dizziness and nausea, whereas the concentrations equal to or higher than 50% are of generally life-threatening character.[7] In addition to the toxicological examination, it was also recommended to analyze the histopathological changes occurring because of the heat.[8] Moreover, the radiological examination is also very important for such cases.

In the present study carried out in Trabzon Branch Office, The Ministry of Justice Council of Forensic Medicine, which is a reference autopsy center in the Eastern Black Sea Region located in northeastern Turkey, it was aimed to obtain region-specific data about bodies found in fire scenes by making use of the demographic characteristics of cases and the crime scene and autopsy findings, to discuss the rarely-seen cases, and to examine the importance of HbCO level in the investigation.

MATERIALS AND METHODS

The autopsy reports prepared in Trabzon Branch Office, The Ministry of Justice Council of Forensic Medicine, for the death cases found in fire scene between 2007 and 2016 were retrospectively examined. The gender and age of cases, the periodic characteristics such as month and season, the cause and location of the fire, the autopsy findings, and the histopathological, radiological, and toxicological results were obtained from the case documents. All the data regarding the determined parameters were entered into IBM SPSS (Statistical Package for the Social Sciences) 24.0 software. Results were stated as mean± standard deviations (SD) values, number (n), and percentage (%). The Chi-square test was used in two-cell and multiple-cell tables and $p<0.05$ is considered significant. The systemic toxicology analyses were performed using AB SCIEX LCMSMS QTRAP 5500 and X500R QTOF devices, whereas the alcohol measurements were performed using Perkin Elmer Clarus 580 HS/GC and the HbCO levels were measured using Radiometer CO-OX ABL 80 Flex.

RESULTS

As a result of analyzing the 10-year archive data, it was determined that 100 (63.3%) of 158 cases, which have been found in the fire scene and undergone forensic autopsy, were male and 58 (36.7%) were female.

156 cases, the identity of which could be determined, were aged between 1 and 97 years. The mean age was calculated to be 48.22±29.20 years.

Of the fires, 101 (63.9%) occurred in house, 22 (13.9%) in vehicle, 20 (12.7%) in outdoor areas such as agricultural land and forest, 5 (3.2%) in indoor spaces of business places, 5 (3.2%) in tandoori, and 5 (3.2%) in environments such as barn, hayloft, tent, and barrack (Fig. 1).

Given the seasonal distribution, it was found that 56 (35.4%) of the cases examined in this study occurred in winter, 44 (27.8%) in spring, 31 (19.6%) in summer, and 27 (17.1%) in autumn (Fig. 2).

In autopsy reports, it was stated that there were 1st degree burns in 1 (0.6%) case, 2nd degree burns in 15 (9.5%) cases, 3rd degree burns in 23 (14.6%) cases, and 4th degree (the carbonization level) burns in 100 (63.3%) cases. However, no burn was detected in 19 cases (12%). In evaluating the burn degrees, the different characteristics of the different body sections were not separately considered. The analyses were performed over the degree of relatively dominant burn.

It was determined that the faces of 61 (38.6%) cases have been changed and become unidentifiable and they could not be recognized by their relatives, and the medical identification of 97 (61.4%) cases could be made by their faces.

It was determined that, out of 158 cases, 22 (13.9%) were taken out alive from the fire scene and then lost their lives after the treatment in hospital for a while.

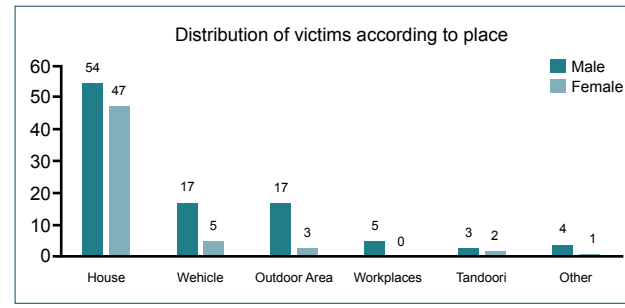

Figure 1. Distribution of victims according to place.

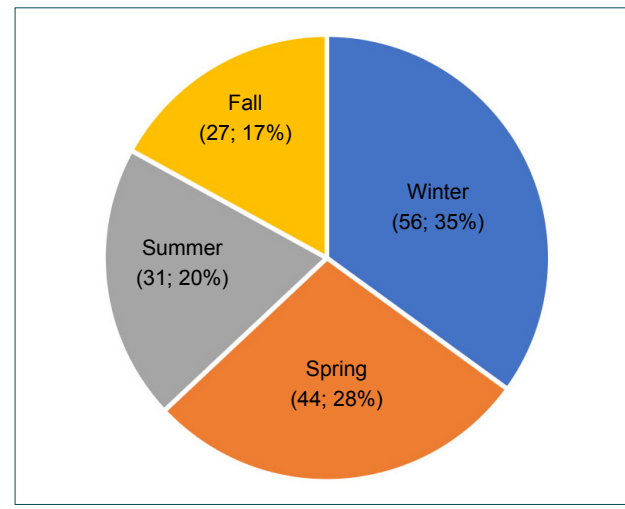

Figure 2. Distribution of the cases according to seasons.

The causes of fires are presented in Table 1.

In toxicological analyses performed, no HbCO was detected in blood samples of 41 (25.9%) cases. The HbCO levels of the cases classified as mild (0.1–10%), moderate (10.1–50%), and high (>%50) are presented in Table 2.

In three cases, the cause of death was only carbon monoxide (CO) intoxication; the highest levels were 80.4%, 84.4%, and 84.8%.

In histopathological analyses, positive pathological findings were found in 40 (24.7%) cases. Among these cases, 3 (1.9%) cases were found to have mild obstruction in measurements performed on internal elastic membrane in the lumen of coronary arteries (obstruction up to 33% of lumen), 14 (8.9%) to have moderate obstruction in minimum 1 of major coronaries (obstruction up to 66% of lumen), and 13 (8.2%) to have severe obstruction (obstruction up to 100% of lumen). Besides that, acute myocardial infarct, subarachnoid bleeding, or gastric bleeding were found in histopathological examination of 9 (5.7%) cases.

Based on all the findings obtained in forensic autopsy and the histopathological and toxicological analyses performed, it was found that the death occurred because of burn and complications in 65 (41.1%) cases, joint effect of burn and CO intoxication in 39 (24.7%) cases, CO intoxication and smoke inhalation in 11 (7%) cases, only the CO intoxication in 24 (15.2%) cases, trauma in 5 (3.2%) cases, firearm injury in 2 (1.2%) cases, and myocardial infarct in 2 (1.2%) cases. The cause of death could not be determined in 10 (6.3%) cases (Table 3).

Considering the results obtained, the files of legal investigations, the crime scene investigations, and witness statements, it was found that the majority (119 cases, 75.3%) of the deaths occurred because of an accident, whereas the cause of death was homicide in 9 (5.7%) cases and suicide in 5 (3.2%) cases. The cause of death could not be determined in 25 (15.8%) cases (Table 4).

By excluding the group of cases with undetected origin, it was determined that there was a statistically significant difference between the homicide-caused deaths and the deaths with other causes (accident and suicide) in terms of the HbCO levels (Table 5).

By grouping the fire scene as outdoor and indoor areas, the comparison made between the HbCO levels of cases is pre-

Table 1. Causes of fire

Cause of fire	n	%
Stove	35	22.2
Electrical household appliances	24	15.2
Traffic accident	19	12
LPG-Propane cylinder	11	7
Candle/cigarette/lighter	7	4.4
Vehicle fuel	7	4.4
Tandoori	5	3.2
Unknown	36	22.8
Others*	14	8.9
Total	158	100

*Others: Terrorist attack, campfire, and forest fire.

Table 2. Carboxyihemoglobin levels

HbCO levels	n	%
0%	41	25.9
1–10%	20	12.7
10.1–50%	65	41.1
>50%	32	20.3
Total	158	100

Table 3. Cause of death

Cause of death	n	%	HbCO levels (Mean±SD)
Burn and complications	65	41.1	8.67±10.38
Burn and carbon monoxide intoxication	39	24.7	32.82±19.90
Only the carbon monoxide intoxication	24	15.2	60.45±14.59
Carbon monoxide intoxication and smoke inhalation	11	7.0	48.88±20.07
Trauma	5	3.2	14.44±16.30
Firearm injury	2	1.2	17.50±2.50
Myocardial infactus	2	1.2	12.15±2.85
Unknown	10	6.3	–
Total	158	100	25.09±24.64

SD: Standard deviation.

Table 4. Origins and ve carboxyhemoglobin levels

Origin	n	%	HbCO levels (mean±SD)
Accident	119	7.3	27.56±24.84
Homicide	9	5.7	7.55±9.22
Suicide	5	3.2	16.68±14.53
Unknown	25	15.8	21.30±26.44
Total	158	100	25.09±24.64

SD: Standard deviation.

Table 5. Origins and ve carboxyhemoglobin levels-2

Origin	n	%	HbCO levels (mean±SD)	p-value
Accident and suicide	124	78.5	27.12±24.57	=0.016
Homicide	9	5.7	7.55±9.22	(Mann-Whitney U)

SD: Standard deviation.

Table 6. Places and ve carboxyhemoglobin levels

HbCO Levels	Places			
	Indoor areas	Outdoor areas	Total	p=0.001 (Pearson Chi-Square)
<10%	41	20	61	
10.1–50%	39	26	65	
>50%	31	1	32	
Total	111	47	158	

Table 7. Places and carboxyhemoglobin mean levels

HbCO Levels		Places		
		Indoor areas	Outdoor areas	p=0.006 (Mann-Whitney U)
	Minimum	0	0	
	Mean	29.63	14.35	
	Maximum	84.8	68.8	
	SD	26.68	14.24	

SD: Standard deviation.

sented in Table 6. The difference between the two groups was found to be statistically significant (p<0.05) (Tables 6 and 7).

Among the cases in which the cause of death was only the CO inhalation and the cases in which the death occurred because of CO inhalation and either burn or smoke inhalation, the mean level of CO was calculated to be 44.1%.

Among 158 cases undergone forensic autopsy, the alcohol was detected in 4 cases and the ethyl alcohol concentrations in the blood samples were found to be 131, 205, 267, and 454 mg/dL.

After examining the medical histories of the cases, it was determined that 21 of the cases had known diseases before they were found in the fire scene. It was found that, among the cases, 10 had plegia as neurologic disease sequel, 6 had psychiatric disorders (psychosis, depression, and bipolar disorder), 1 had dementia, 1 was hearing-impaired, and 3 cases had various physical disorders (senility, gonarthrosis, and coxarthrosis) at the levels influencing the mobilization.

DISCUSSION

In all the events gaining a judiciary character, each of the suicide, homicide, and accident origins must be carefully examined without any exceptions, and all the details such as negligence, abuse, and occupational accident that might be related with the fire must be carefully analyzed. Although the origin of accident is the first point coming to mind for the cases and deaths thought to be related with fire, these fundamental principles should be carefully considered and all the options should be used for the criminal analyses.

As a result of the analysis of 10-year archive, it was determined that there were 158 cases found in a fire scene and undergone forensic autopsy. In literature, it was reported that males constitute the majority of fire-related cases.[5,6] In the present study, males constituted the majority of individuals having burn traumas resulting in death 100 (63.3%) males and 58 (36.7%) females.

Given the spatial distribution, it was found that 101 (63.9%) of the cases were exposed to fire in the house environment, 22 (13.9%) in a vehicle, 20 (12.7%) in outdoor areas such as agricultural land and forest, 5 (3.2%) in business places, 5 (3.2%) in tandoori, and 5 (3.2%) in environments such as barn, hayloft, tent, and barrack. Although it was reported in the literature that the events occurred mainly in closed areas, several studies reported the percentage of in-vehicle events to be higher.[9]

Given the seasonal distribution in the present study, it can be seen that 56 (35.4%) of the events occurred in winter (December, January, and February), 44 (27.8%) in spring (March, April, and May), 31 (19.6%) in summer (June, July, and August), and 27 (17.1%) in autumn (September, October, and November). In some of the previous studies, the traumas originating from the household heating systems in winter and outdoor area fire in summer are reported.[9]

In forensic autopsy procedures of the cases, it was determined that there were 1st degree burns in 1 (0.6%) case, 2nd degree burns in 15 (9.5%) cases, 3rd degree burns in 23 (14.6%) cases, and the carbonization level burn in 100 (63.3%) cases. No burn was detected in 19 cases (12%). Although it was reported in the literature that the most frequently seen type of burn is 2nd degree burns, it was also reported in a study carried out in an emergency service unit that the 1st degree burns constitute 10%.[10] In the studies involving the hospitalized patients, it was observed that the percentage of patients with 2nd degree burn trauma increased to 88% and the percentage

of those with 3rd degree burn trauma increased up to 41.9%.[11,12] These studies did not involve the individuals admitting to the hospitals. The frequency of observing the burn degrees in autopsy studies is different. In a study carried out by Buyuk et al.[6] on 320 burn cases resulting in death, it was reported that 2nd degree burns constituted 12.5% of the total, 3rd degree burns 30.3%, and carbonization-level burns 57.2%. In another study carried out in İstanbul, it was found that the cases with 4th degree burn injuries constituted 83.6% of all the cases resulting in death. The reason for high rates in those studies is that the possibility of complication and primary damage in vital organs increases as the degree of burn increases.

It was determined that 22 (13.9%) of 158 cases were taken out alive from the fire scene and then lost their lives after the treatment in hospital for a while. In this group, the complications of burn trauma significantly influenced the death. Specifically, sepsis is a severe life-threatening complication.[13]

Recent publications report at least a 5% negative autopsy rate in the advanced centers. This rate varies according to the case characteristics, experience of the specialist, and center characteristics.[14] In the present study, the cause of death could not be determined in 10 cases constituting 6.3% of the total. This is mainly caused by the case characteristics in the present study. Because, the corpses had turned into ash due to extensive burn damage, or despite the cause of death was pathological, tissues were severely deformed to the extent that would avoid histopathological examination.

The cases were grouped based on the evidences found, the files of legal investigations, the crime scene investigations, and the witness statements, it was determined that the cause of death was the accident in the vast majority of the cases (119 cases, 75.3%), whereas 9 (5.7%) were murdered and 5 (3.2%) cases were suicide-related death cases. The origin of case cannot be detected in 25 (15.8%) events (Table 4). In the previous studies, the percentage of accident-related traumas was reported to be high.[15] In another 10-year study, the percentages similar to the values reported in the present study were reported.[16] The absence of a common homicide and suicide method explains why the cases were generally the accident-originated ones.

The significant difference between the origins and the HbCO levels (Table 5) is very important. It is widely seen that the homicide victims are put into a fire scene after the murder and the fire is started intentionally to obfuscate the evidences. In such cases, radiological, macroscopic, and microscopic pathological analyses are very important. Thus, metallic sub-

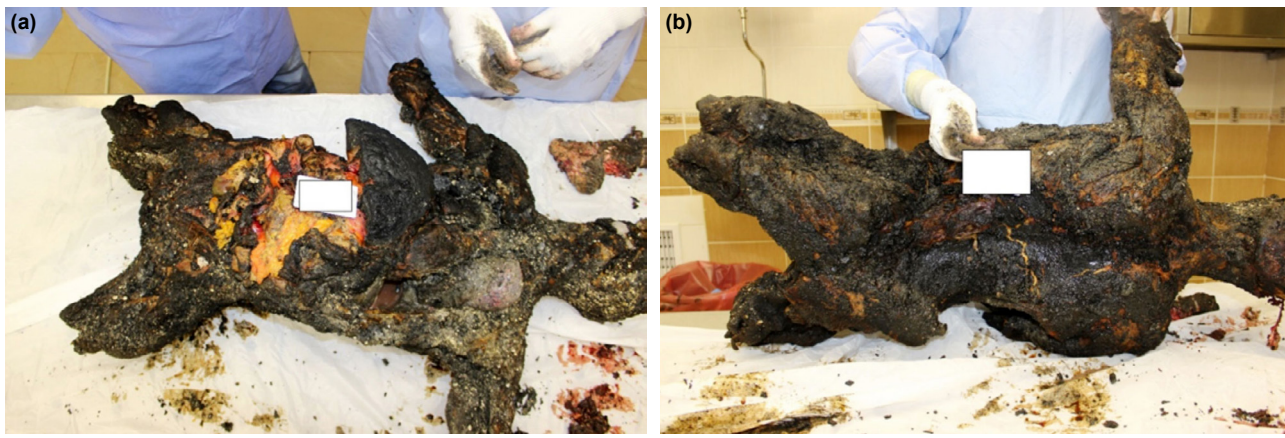

Figure 3. (a) External frontal view of a corpse taken out of a fire scene. **(b)** External posterior view of a corpse taken out of a fire scene.

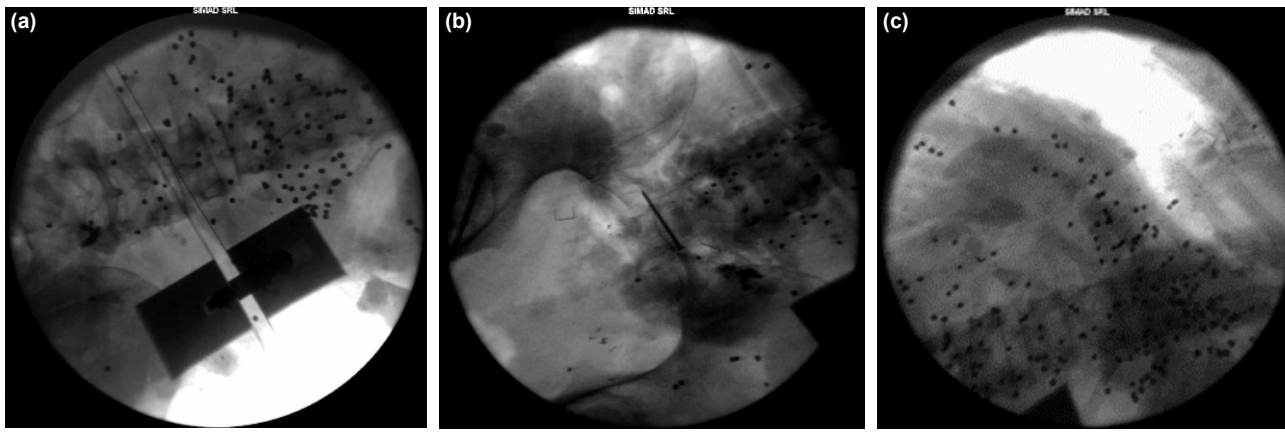

Figure 4. (a-c) Scopy images of a corpse taken out from fire scene. The pellet-like metallic images in the photos.

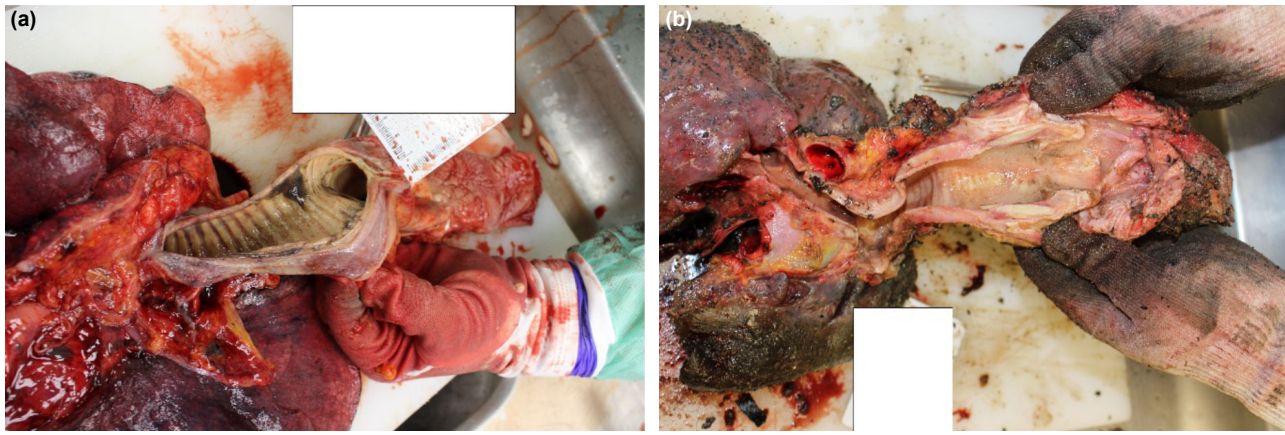

Figure 5. (a-b) Determining the carbon residuals in respiratory tract (trachea): carbon residuals in trachea below the vocal cords (right side) and no carbon residual observed in corpse taken out from fire scene (left side).

jects such as firearm bullet and macroscopic and microscopic organ pathologies can be detected (Figs. 3–5).
Besides being an important indicator for the vitality assessment in fire scene, the HbCO levels can also be used in determining the origin. For this reason, the most important part of the post-mortem toxicological analysis is the HbCO level analysis.

When the fire scenes were groups as indoor and outdoor areas, the results of the comparison between CO levels are presented in Tables 6 and 7. The difference between the two groups was found to be statistically significant ($p<0.05$) The fire takes place sometimes directly in outdoor spaces (agricultural land, forest, etc.) and sometimes in indoor but well-ventilated spaces. Inhalation of the fire-caused gases and particles at lower levels explains why the HbCO levels were found to be lower when compared to the indoor cases.

For the cases, in which the cause of death was only the CO inhalation, and the cases, in which the death occurred because of CO inhalation and the effect of either burn or smoke inhalation, the mean level of CO was found to be 44.1%. Severe muscular dystrophy occurs when the blood HbCO level reaches 50%, whereas death occurs at the levels between 60% and 80%. Besides that, it should be noted that the HbCO concentration at 20% might cause death among the individuals having severe coronary disease, severe chronic lung disease, or atherosclerosis in the cerebrovascular system.[17]

In the 10-year period analyzed in the present study, 8695 autopsy procedures were performed in Forensic Medicine Institution's Trabzon Forensic Medicine Department, which is a reference autopsy center in the geographic region. The ratio of fire-related death is 1.82% in the cases undergone autopsy. In another retrospective study carried out on the period between 2009 and 2016 in the same reference center, the ratio of death because of isolated CO intoxication was calculated to be 3.01%.[18] Regardless of the relationship with fire, CO-caused deaths are commonly seen in forensic medicine practices.

In the present study, the alcohol was detected only in 4 out of 158 cases. In the literature, there are studies reporting alcohol in 69% and 80% of the fire victims.[19,20] We believe that the difference is related with the environments, in which the fire took place, and the region, in which the studies were carried out. When it exceeds a specific level, the blood alcohol level has an inhibitory effect on the central nervous system.[21] It is known that concentrations above 400 mg/dL may lead to coma and death. However, death may not occur at higher doses in chronic alcoholics and due to individual and genetic factors.[22] The authors of the present study consider that the blood alcohol levels detected in our cases have facilitated CO poisoning. For example, HbCO level was 84.4% in one case with a blood ethyl alcohol level of 454 mg/dL. Therefore, the main reason for death was reported as CO intoxication in such cases.

This may cause accidental fires and prevent the individual from escaping from the fire scene. The use of alcohol and soporiferous/narcotic substances draws attention as a facilitating factor.[23] In literature, the cases in which the substance addition accompanies the CO intoxication were reported.[24]

When the medical backgrounds of the cases were examined, it was found that 21 cases had known diseases. It was determined that 10 of the cases had plegia as neurologic disease sequel, 6 cases had psychiatric disorders (psychosis, depression, and bipolar disorder), 1 case had dementia, 1 case had hearing impairment, and 3 cases had various physical disorders (senility, gonarthrosis, and coxarthrosis) at the levels preventing the mobilization. The complication risk is at high levels especially for the elderly individuals with comorbidities, high-degree and large-area burns and it may course mortally. Among the comorbidities, especially the hearing and visual impairment, diabetes causing sensory neuropathy, physical disorders such as arthritis, and mental disorders are related with the burn

trauma, especially among the elderly individuals.[25] Besides that, it was also reported that incurable epilepsy with seizure also poses a significant risk.[26] As a special medical condition, pregnancy also increases the mortality of both baby and mother.[27]

Conclusions

In the present study, it was determined that the cases found in fire scenes died mainly in indoor spaces, in places such as living room and kitchen where the household appliances such as stove and electrical-gas appliances are used, and that the death occurred mainly because of exposure to high CO concentration. Accordingly, it is believed that the use of simple CO sensors in places such as living room and kitchen, where individuals spend more time and CO intoxication is observed more frequently, would decrease the incidence of such deaths.

Starting from the crime scene investigation, a detailed radiological, toxicological, and pathological investigation must be performed for the persons taken out from the fire scenes. The toxicological examination must include various factors such as HbCO, cyanide, and use of alcohol and narcotic substances influencing the will and mobilization. In the present study, it was aimed to reveal the relationship between HbCO levels and other variables among the cases taken out from the fire scene and undergone autopsy. It was observed that the HbCO levels can be used in determining the space in which death occurred, the origin, and the comorbidities of the individual. As expected, a remarkable increase is observed in the HbCO levels in corpses taken from the fire scenes and the CO intoxication and the other factors facilitated by CO inhalation come to the forefront as causes of death. Moreover, the present study also showed that, in addition to these expected death mechanisms, the firearm injury and the other traumas might also be the cause of death.

Limitations

In the present study, the autopsy and crime scene investigation reports were retrospectively examined. Larger case groups are needed for analyzing the HbCO levels of corpses, which were taken out from fire scenes, in terms of the location and origin.

Ethics Committee Approval: This study was approved by the Ministry of Justice, Forensic Medicine Institute Presidency (Date: 23.05.2017, Decision No: 21589509/251).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: H.I.A., H.C.K.; Design: H.I.A., H.C.K., H.B.; Supervision: E.O., H.C.K.; Resource: E.O., H.C.K.; Materials: H.C.K., H.B.; Data: H.I.A., H.B., M.A., G.S.K.; Analysis: H.I.A., H.C.K., G.S.K.; Literature search: H.I.A. M.A. H.C.K.; Writing: H.I.A., M.A., G.S.K.; Critical revision: H.I.A., E.O., H.C.K.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Yangın ilişkili ölümlerin değerlendirilmesi: Otopsi çalışması

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AMAÇ: Yangın birçok nedenden dolayı ortaya çıkabilen, canlıların hayatını tehdit eden ve ekonomik zarara sebep olan önemli bir halk sağlığı sorunudur. Yangın ortamından çıkarılan kişilerde yapılacak ilk tıbbi incelemeler, olay yeri incelemesi ve adli soruşturma önemli deliller ortaya koyabilmektedir.
GEREÇ VE YÖNTEM: Adli Tıp Kurumu Trabzon Adli Tıp Grup Başkanlığı'nda 2007–2016 yılları arasındaki dönemde, yangın ortamında bulunan ölüm olgularına ait otopsi raporları geriye dönük olarak incelendi.
BULGULAR: On yıllık arşiv taraması neticesinde yangın ortamında bulunan ve adli otopsileri yapılan 158 olgunun 100'ünün (%63.3) erkek, 58'inin (%36.7) kadın olduğu tespit edildi. Orijini tespit edilemeyen grup dışlanarak; cinayet orijinli ölümlerle ile diğer orjinli ölümler (kaza ve intihar) arasında karboksihemoglobin seviyeleri açısından yapılan değerlendirmede iki grup arasında istatistiksel olarak anlamlı farklılık bulundu. Yangın ortamı açık ve kapalı alanlar olarak gruplandırıldığında olgularda tespit edilen karboksihemoglobin düzeylerinin karşılaştırılması Tablo 6'da gösterilmiştir. İki grup arası fark istatistiki olarak anlamlı bulundu ($p<0.05$).
TARTIŞMA: Yangın ortamından çıkarılan kişilerde olay yeri incelemesinden başlanarak, iyi bir radyolojik, toksikolojik ve patolojik inceleme yapılması esastır. Toksikolojik incelme, karboksihemoglobin, siyanür ve irade ve hareketi etkileyecek alkol, uyutucu, uyuşturucu vb gibi birçok maddeyi kapsamalıdır. Karboksihemoglobin düzeyleri ölümün meydana geldiği mekan, orijin ve kişideki mevcut ek hastalıklarla ilgili bilgi verebileceğini göstermektedir.
Anahtar sözcükler: Adli tıp; karboksihemoglobin düzeyi; otopsi; ölüm; yangın.

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