



Case Report

# Phosgene Inhalation in Fire-Related Deaths: A Case Report of Two Lovers Burnt in a Travelling Carousel

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**Abstract:** Fire deaths present several diagnostic challenges for the forensic examiner, the most significant of which is the identification of the cause of death and the evaluation of the morphological consequences of heat injuries in the ante-mortem and post-mortem periods. Here, we describe the case of two young lovers found dead inside a travelling carousel destroyed by a fire. Circumstantial evidence of disputes between families running the town fair raised the suspicion of intentional arson. Comparative analysis of crime scene investigation, radiological, autptic, histological, and toxicological findings revealed signs of vitality (i.e., presence of soot deposits inside the respiratory and digestive tracts, heat damage to the respiratory mucosa) and identified fatal asphyxia from haemorrhagic pulmonary oedema as the cause of death. Since the experimental burning of plastic samples collected from a similar carousel demonstrated the significant production of phosgene, the death of the two lovers was attributed to the probable inhalation of this gas. The case presented here underlines the importance of a multidisciplinary approach of any fire-related death, providing an insight into circumstantial and forensic (autopsy, toxicological, and immunohistopathological) elements useful in raising suspicion of possible toxic gas inhalation. In the presence of high levels of PVC materials at the fire scene and pulmonary oedema at the autopsy, with no alternative causes of death, the forensic pathologist must suspect a fatal exposure to phosgene.

**Keywords:** fire victim; burned body; charred corpse; crime scene investigation; forensic radiology; forensic pathology; forensic histopathology; time since death; identification; forensic toxicology



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## 1. Introduction

Among the most challenging forensic investigations, fire deaths are not uncommon in medical–legal practice. Forensic pathologists are often asked to interpret the cause, time, and dynamics of death, as well as to identify the body, with only limited evidence available. Although charred bodies are often extensively damaged, the morphological findings may cover a broad spectrum, ranging from minor, local, superficial burns of the skin, to complete incineration, with calcined skeletal remains and loss of any soft tissue [1,2]. In general, fire-related deaths may be immediate or delayed, as a result of direct thermal injuries to the body, hypovolemic shock, acute respiratory distress syndrome (ARDS) or smoke inhalation [3–5]. Indeed, several toxic gases released during thermal combustion, such as carbon monoxide, cyanide or phosgene have been demonstrated to cause noxious asphyxiant effects [6,7]. As regards the latter substance, human exposure to phosgene concentrations greater than 1 ppm × min may produce a transient protective vagus reflex with rapid shallow breathing and moderate irritation of the eyes and upper respiratory tract. When the inhaled dose is superior to 300 ppm × min, it may result in the death of some individuals [8]. At the dose of 500 ppm × min, significant pulmonary oedema

appears within 3 h, with death following within the next 24 h [9], and a higher dose of phosgene ( $\sim 600$  ppm  $\times$  min) may cause death within minutes [10].

To our knowledge, only a few studies have been conducted on phosgene intoxication, primarily for clinical or toxicological purposes [11–14]. In contrast, this topic is not currently studied from a forensic perspective, with its medico-legal implications, especially in fire-related deaths. Here, we report two cases examined through an integrated radiological, immunohistochemical, and toxicological approach and discuss the possible role of phosgene in producing extensive and fatal lung oedema.

## 2. Case Report

Early in the morning, at the conclusion of a local festival, a blaze burned a travelling carousel placed in a town square. After the firefighters extinguished the flames, two burned bodies on the pavement of the carousel were found. The victims were a couple of lovers known in the community: a 20-year-old boy and a 16-year-old girl. As there were disputes between the families who organized the fair, the authorities immediately considered the possibility that the fire might have been intentionally started. The forensic department was therefore instructed to detect any evidence indicative of third-party action and to establish the cause and the dynamic of the deaths.

### 2.1. Death Scene Investigation

Both victims were found lying on the pavement of the carousel, with the male and the female in a supine and a prone position, respectively (Figure 1). The Fire Department technicians pinpointed the origin of the fire right between the two bodies, excluding both the presence of accelerants and accidental electrical ignition.



**Figure 1.** Death scene: (A) the burnt carousel, and (B) a similar intact travelling carousel. Charred bodies found lying on the pavement of the carousel (C): the female (pink arrow, and in particular (D)), and the male (blue arrow, and in particular (E)).

### 2.2. Post-Mortem Radiological Examination

A comprehensive analysis using Multi Slice Computed Tomography (MSCT) was conducted on both corpses prior to autopsy (Figure 2). The results highlighted burst fractures of the skulls, with loss of bone and cerebral material, multiple rib fractures and distal limb amputations. No retained metal objects were detected.



**Figure 2.** Post-mortem Multi Slice Computed Tomography (MSCT, CT bone window): (A) male, (B) female.

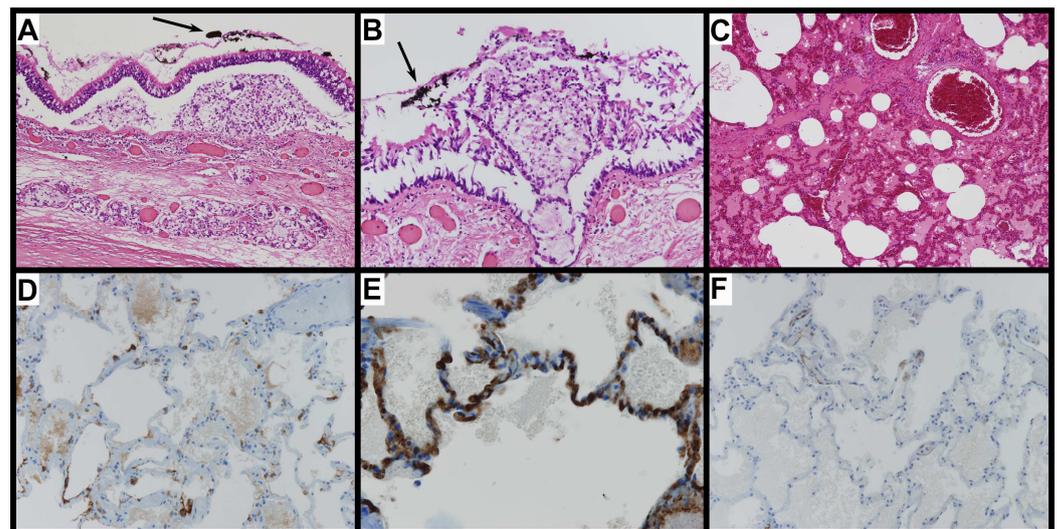
### 2.3. Autopsy Findings

At external examination, the corpses presented a typical “pugilistic attitude”, with flexion of elbows and knees and clenching hands (Figure 1C,D). The soft tissues appeared

widely incinerated, with interruption of abdominal and thoracic walls integrity. The observation of the bone fractures radiologically detected led to the evaluation of the burned margins and the absence of haemorrhagic infiltration. The major internal findings consisted of oedema and hyperaemia of the upper airway mucosa, with pinkish foam and soot inside the respiratory tract of both victims, from the trachea to the terminal bronchial branches. Similarly, soot deposits were observed in the oesophagus and stomach. Massive and diffuse haemorrhagic oedema affected the lung parenchyma. There was no structural abnormality in the hearts of both deceased victims, with pervious coronary arteries. Widespread poly-visceral heat lesions were also detected. No evidence of trauma was revealed in both the corpses.

#### 2.4. Histological and Immunohistochemical Analysis

Histological examination detected the presence of soot deposits in trachea and bronchial mucosa, along with mucosal oedema, vascular congestion, and epithelial detachment. Massive oedema and erythrocytes were also detected in the lungs and the alveoli. There was no evidence of fibrin and/or inflammatory infiltrates. The immunohistochemical evaluations of lung samples were performed to identify the cell types involved in the damage. Epithelial membrane antigen (EMA) and endothelial markers (CD-34 and F-VIII) were used [15], revealing severe alveolar necrosis, without significant damage of the endothelium (Figure 3).



**Figure 3.** Histological and immunohistochemical results: (A,B) upper respiratory tract, H&E staining—magnification 62 $\times$  and 125 $\times$ , respectively. Soot deposits in trachea–bronchial mucosa (black arrows) and epithelial detachment; (C) lungs, H&E staining—magnification 125 $\times$ . Haemorrhagic alveolar oedema; (D) lungs, IHC CD34 stain—magnification 160 $\times$ . Integrity of the vascular endothelium; (E) lungs, IHC F-VIII stain—magnification 320 $\times$ . Integrity of the vascular endothelium; (F) lungs, IHC EMA stain—magnification 160 $\times$ . Diffuse alveolar necrosis.

#### 2.5. Toxicological Analyses

Toxicological analyses were performed on post-mortem blood (sampled from the cardiac left ventricle), urine and tissues using gas chromatography coupled with mass spectrometry (GC-MS) for different classes of drugs of abuse and psychoactive substances. Blood was tested for alcohol, and for other volatile substances, by headspace gas chromatography with flame ionization detection (HS-GC/FID). The cyanide determination in blood was performed using solid phase microextraction and gas chromatography coupled with mass spectrometry [16]. The analysis of carboxyhaemoglobin (CO-Hb) in the post-mortem blood was carried out by UV-visible determinations performed on a Varian CARY50 (Torino, Italy) spectrophotometer at 532 and 558 nm. In a 10 mL glass tube,

20 µL of blood was suspended in 5 mL of 0.1% sodium carbonate, and 4 mg of sodium dithionite was added and gently shaken for 5 min to obtain cell lysis. The solution was added to 0.5 mL of sodium hydroxide and incubated at room temperature for 5 min. The absorbance at 558 and 532 nm was read; the ratio (558 nm/532 nm) was correlated to %COHb [17]. Toxicological results excluded any alcohol or drug intoxication; CO-Hb and cyanide blood concentrations were 14% and 0.3 µg/mL, respectively, in the male victim; 15% and 0.4 µg/mL, respectively, in the female victim.

#### *2.6. Technical Inspections and Experimental Burning Analyses*

As the carousel was destroyed by the fire, a similar carousel was examined by technical experts. The structure was found to be formed of a steel frame, with partition panels and internal tools largely made of polyvinyl chloride (PVC). Samples of this plastic material were then collected and experimentally burnt, together with uncombusted residues seized at the death scene, to analyse the fumes produced during the fire. For this purpose, a Chemcassette Toxic Gas Detection device, with an optical system, scanned the presence of gas, evaluating the colour changes of a chemically impregnated paper tape. These analyses demonstrated an extensive production of phosgene (carbonyl dichloride).

### **3. Discussion**

In the present case, circumstantial evidence immediately suggested that the fire might be either a concealment of the corpses or an effort to financially harm the carousel owners, which resulted in the deaths of the two victims. Since the crime scene inspection, even with the cooperation of the Fire Department engineers, could not differentiate accidental ignition from arson, the role of the forensic pathologist in identifying the causes of death was essential. Radiological investigations and external cadaveric examinations excluded the presence of traumatic injuries; likewise, the toxicological analysis refuted the hypothesis of an acute drug/alcohol intoxication. The autopsy revealed signs of vitality: presence of soot deposits inside the respiratory (only partially occluding the airways) and digestive system, along with heat damage to the mucosa of the upper respiratory tract (with oedema, mucosal bleeding, and vesicular detachment) [18]. These findings indicated that the victims were still alive during the fire and that they inhaled hot fire fumes. Such evidence disproved the hypothesis of corpse concealment and confirmed the role of fire in the death of the two victims.

As for the manner of death, carbon monoxide and cyanide are common substances involved in the determination of fire-related deaths [6,7]. In the case here presented, in both victims, CO-Hb concentrations were above 10%, suggesting that the persons were exposed to fire fumes while alive; although being potentially toxic, CO-Hb and cyanide blood levels were considered non-lethal [19,20]. Instead, the gross and microscopic findings identified a massive pulmonary oedema, the extension of which was clearly incompatible with life. Based on the immunohistochemical analysis of specific markers for endothelium and alveolar epithelium [15], severe alveolar necrosis was identified as the cause of the extensive lung damage induced by the inhalation of irritative toxic gases [21,22]. Together with the results of the experimental incineration of the plastic samples collected, which demonstrated the significant production of phosgene, this consideration led to the conclusion that toxic gas inhalation was the most probable cause of the two deaths. Despite the absence of detectable phosgene concentrations in the cadaveric fluids, phosgene indeed is a colourless, extremely volatile compound (with a very short half-life), which is a combustion product of certain chlorinated hydrocarbons such as PVC, integrated analyses of the collected data revealed the major role played by this gas in the cause of the deaths. The inhalation of this gas entails surfactant depletion, increased permeability of the alveolar–capillary membrane, chemical reactions with proteins, lipids, and nucleic acids in the alveolar tissue, along with the significant release of inflammatory mediators and reactive oxygen species (ROS). When these excessive ROS are insufficiently scavenged, they contribute to the damage of the pulmonary endothelial cells and alveolar epithelial

cells, resulting in pulmonary oedema and atelectasis, and finally the development of ALI (acute lung injury). This may result in exudate and accumulation of erythrocytes in the alveolar spaces and the formation of fatal pulmonary oedema [23,24].

The elevated concentration of phosgene in the air inside the carousel, resulting from the presence of a high quantity of PVC, along with the absence of apparent escape attempts by the victims from the source of the fire, suggest that the deaths occurred rapidly. Thus, based on the cause of death, the absence of accelerants, and the identification of the origin of the fire right between the two lovers, an accidental asphyxia by inhalation of phosgene was considered the most likely manner of death. The file was dismissed by the judge.

As demonstrated in this case, exposure to toxic substances other than carbon monoxide and cyanides must be considered as a potential cause of death when charred corpses are discovered. There are very few reports dealing with lethal phosgene inhalation in forensic literature, and none addresses the topic from an autoptic perspective. Consequently, our work aims to provide forensic pathologists with information useful for raising suspicion of fatal phosgene poisoning, such as the presence of high levels of PVC at the death scene and the evidence of pulmonary oedema and severe alveolar damage found at autopsy and histology.

Furthermore, this study emphasizes the absolute need for a standardized protocol in approaching fire-related deaths, which has not yet been established. Currently, there are only recommendations, such as those proposed by Baldino et al. [25], which suggest using a multidisciplinary approach (including circumstantial, autoptic, histopathological, toxicological, and genetic analyses), while leaving wide discretion to individual experts. With the implementation of an accredited algorithm, it will be possible to identify the specific steps required to determine the cause and dynamics of death in complex autopsy cases, thus reducing the subjectivity of evidence interpretation [26–28].

#### 4. Conclusions

The presented two fatal phosgene inhalations underline the importance of integrating all available information (death scene investigation, radiology, histology, and toxicology data) for identifying the exact cause and manner of death. As proposed in our brief report, the presence of a high level of PVC materials at the fire scene and pulmonary oedema at the autopsy, with no alternative causes of death, are valuable elements in raising suspicion of a possible toxic gas inhalation. These findings should lead the forensic pathologist to perform immunohistochemical analyses and experimental burnings, which can be useful investigative tools when dealing with compounds (such as phosgene) characterized by a very short half-life in body fluids and tissues, for which even well-timed toxicological analyses might test negative.

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