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CASE REPORT

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Analytical Aspects of Volatile Substance Abuse (VSA)*

ABSTRACT: Through a case report, the authors illustrate the volatile substance abuse (VSA) toxicological investigation difficulties mainly due to evaporation of the compounds from postmortem samples and to the lack of reference data for interpretation. A 17-year-old man, student in a chemistry institute, was found dead with a plastic bag placed over his head. Several chemical substances were found in his belongings. Autopsy findings included serious pulmonary lesions and hemorrhagic digestive ulcerations. A large screening of drugs and toxic compounds and selective analyses for several classes of drugs of abuse were carried out in the autopsy samples. In particular, a headspace (HS), -gas chromatography/-mass spectrometry (GC/MS) technique was used to screen for volatile substances and metabolites in the biological samples and for residues of volatile substances on the surface of the plastic bag and in the chemicals found on the scene. The main analytical finding was the presence of alkanes (heptane, methyl-2-pentane, methyl-3-hexane, methylcyclohexane) in the gastric content. The literature data, VSA practices, long time-delay between death and autopsy, preservation conditions of the biological samples before analysis, and in-lab experiments on evaporation of volatile substances were considered to interpret this result. The present fatality was attributed to VSA with a gasoline-based stain remover like "eau écarlate™," associated with a hypoxic recreation practice using a plastic bag.

KEYWORDS: forensic science, forensic toxicology, abuse, volatile substance, hypoxic recreation practice, headspace-gas chromatography/mass spectrometry

Volatile substance abuse (VSA), the deliberate inhalation of volatile substances to obtain psychoactive effects, seems to be a frequent practice in France, as well as in other countries, mainly among adolescents (1,2). This abuse ordinarily involves household products which can appear as an attractive alternative to "usual" drugs as they are legal, freely available, and cheap: hydrocarbons from lighter refills, fuel gas, aerosol propellants, chlorofluorocarbons such as those found in aerosols, refrigerants, fire extinguishers, toluene, xylene, in contact adhesives, glues, paints, thinners, halogenated solvents like trichloroethane, trichloroethylene, or tetrachloroethane from typewriter correcting fluids, degreasing agents, dry cleaning fluids, nitrous oxide used as propellant in spray canisters for whipped cream; nitrites used as poppers available in sex shops (1–4). Although the ratio of deaths to non-fatal inhalation practices remains low, VSA carries the risk of a unpredictable and unpreventable "sudden sniffing death syndrome," during or soon after VSA (5,6). This syndrome is the consequence of acute exposition with volatiles resulting in immediate and early pulmonary and cardiovascular effects: persistent intrapulmonary physiological shunting, hypoxemia, cardiac arrhythmia, bradycardia and hypotension (7,8).

Toxicological investigations and examination of the scene of death are critical to identifying volatile substance abuse by inhalation as the cause of death, because anatomic autopsy findings will typically be nonspecific (6). In forensic toxicology, VSA investigations should involve the search of a very wide range of substances in autopsy samples (blood, urine, gastric content and lungs). Besides, special attention should be paid to urinary metabolites, e.g., trichloroethanol and trichloroacetic acid after trichloroethylene inhalation. In addition, highly sensitive and specific analytical methods should be used, as evaporation of the substances from postmortem samples is one of the main causes of the difficulties of VSA analytical investigations (the other one being the lack of reference data for interpretation). The present, unusual case report illustrates these issues.

Case History

A 17-year-old man, student in a chemistry institute, was found dead in his bedroom by his mother at daybreak. The body was dressed and, as a particularity, the corpse was found in sitting position on a bed, his head covered with a black plastic bag with no link around the neck.

The assumptions that it could be a homicide or a suicide were swiftly ruled out by the police. Several chemicals (as pure substances or in domestic/industrial mixtures) were found by the police in the belongings of the young man, including: oxidants (ferric

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chloride, ethyl methyl ketone peroxide); acids (phosphoric acid, acetic acid); and petroleum derivatives including acetone, ethoxyethyl, developers for photography containing solvents ("White Spirit," xylene), and a stain remover bottle called "eau écarlate™." Neither suspect lesion, nor wound was found during corpse examination. Hemorrhagic regurgitation marks around the mouth and nose and a lip wound due to self bite were observed. The autopsy, performed two days after death, revealed an oedematous and inflammatory oropharyngeal tract, and a bilateral pulmonary oedema. Peripheric and cardiac blood samples (2 × 15 mL) were sampled and placed in two 30 mL glass vials. Bile (1 mL), humor vitreous, brain, kidney, liver, lung, heart and urine (20 mL) samples were put in 30 mL plastic vials. The gastric contents (30 mL) were collected in a 50 mL plastic vial.

These biological samples and the plastic bag were sent by mail at ambient temperature to the laboratory for forensic toxicological analysis. In addition, samples of the chemicals seized by the police were sent for comparison with the results of the postmortem investigations.

Material and Methods

On the receipt at the laboratory, all the samples were kept frozen at −20°C until analysis. A large screening of drugs and toxicants was performed in all samples using both high-performance liquid chromatography coupled to a diode array detector (HPLC-DAD) and gas chromatography/mass spectrometry (GC/MS). More selective analyses for several classes of therapeutic drugs, drugs of abuse, alkaloid poisons, mineral toxicants . . . were carried out with various methods using HPLC-DAD, liquid chromatography-electrospray-mass spectrometry (LC-ES-MS) and GC with various detection modes.

In particular, a headspace (HS)-GC/MS technique was used to screen for residues of volatile substances on the surface of the plastic bag as well as in the chemicals, and for volatile substances and metabolites in blood, lungs, urine and gastric content. Briefly, samples were prepared as follows: 1 mL or 1 g (bag) of materials was introduced in a 22 mL HS-vial, which was rapidly sealed with a silicone septum and aluminum cap. Then, the vial was introduced in an automated HS40XL head-space sampling system (Perkin-Elmer, Norwalk, CT) to undergo a first step of volatilization of the compounds of interest (80°C for 20 min) followed by pressurization at 17 psi for 2 min using helium. Seventy μL of the headspace gas were automatically sampled with a needle heated at 90°C and transferred through a transfer line heated at 100°C with helium as carrier gas at 10 psi to a 5890 series II gas chromatograph (Hewlett-Packard, Palo Alto, CA) for splitless injection. Separation was performed on a 30 m × 0.25 mm i.d. 624CB column (Varian, Courtaboeuf, France). The column temperature was set at 35°C for 5 min, and then ramped up to 150°C at 15°C/min with a plateau at this final temperature for 5 min. Identification of the volatile compounds was performed in the scan mode (m/z 27 to 200) using a MS Engine 5989A HP detector (Hewlett-Packard, Palo Alto, CA) by comparison of the obtained mass spectra with those of three libraries: PMW—Tox2 (9), WILEY 7N (10) and an in-house library.

Results

Overall the autopsy samples, only one positive result was found: several alkanes were found in the gastric contents, in particular, methyl-2-pentane, methyl-3-hexane, heptane, and methylcyclohexane. In addition, these slightly volatile alkanes appeared to be similar to those found in one of the chemicals found in the belongings of the victim: the stain remover called "eau écarlate™." In particular, the same branched and cyclic alkanes were present on the chromatogram (Fig. 1). The alkanes detected in the gastric contents were not found in blood or in urine (despite a low detection limit in blood, of ca. 0.5 ng/mL for heptane). No other drugs or toxic compounds were found in the autopsy samples.

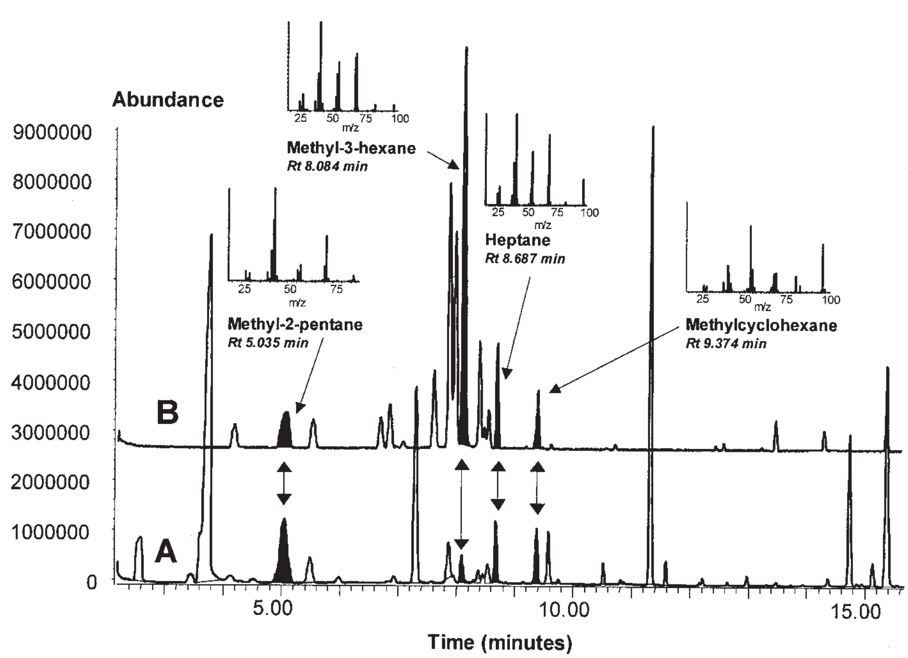

FIG. 1—*HS-GC/MS chromatograms of volatile substances from the gastric content (A and the stain remover B).*

Discussion

Due to the presence of these alkanes in the gastric contents and the case context, we considered the possibility of a sniffing practice, and/or drinking as a deviance from sniffing practice. Because of their composition (complex mixtures of various hydrocarbons: heptane and isomers, hexane and isomers, cyclohexane, branched alkanes . . .), cleaning fluids like “eau écarlate™” have been associated with VSA fatalities (2,11). The direct abuse-related deaths with such hydrocarbons are commonly attributed to anoxia and cardiac arrhythmia which seem to be due to a “sensitization” of the heart to adrenaline, as shown in experimental conditions (5,12). Moreover, a fatality with the same commercial product had been already reported (13). So, the hypothesis of a VSA with a gasoline-mixture, which could be “eau écarlate™,” was considered acceptable. In addition, bad sample handling and storage conditions could explain the absence of alkane traces in the other biological samples: there was a long time delay (two days) between death and sampling, the containers used were not air-tight nor filled up, and the samples were sent to the laboratory by mail at ambient temperature. When a VSA case is suspected, samples should be placed in gas-tight containers (HS vials with a teflon-lined septum represent the most satisfactory solution in order to reduce the loss of volatile substances). Moreover, samples should be stored in containers with minimum headspace, under cold conditions (4°C or less) prior to analysis (14).

Sniffing practices include: sniffing at the neck of the container, sniffing through a cloth (i.e., handkerchief), or using a bag in which the substance is directly poured or a support soaked with the chemical placed (2,4). In this fatality, no support (paper, or cloth…) was found inside the bag. Likewise, a scrupulous examination of the internal face of the plastic bag revealed no macroscopic residues traces. However, a simple experiment revealed that “eau écarlate™” deposited on a plastic bag was evaporated in less than 2 min at room temperature without any visible residues on the black plastic surface. Also, in order to investigate the possible role of the bag in this potential VSA practice, we conducted several experiments and analyses. In particular, we examined the possibility to detect, using HS-GC/MS analysis, residues on the plastic surface after complete evaporation of “eau écarlate”: 2 mL were poured on a similar black plastic bag and allowed to evaporate; after 2 days at room temperature in open air, screening for volatiles was performed on the bag. Alkane residues were found on the surface of this test bag, whereas no volatile compound was found on the bag seized by the police. Such results suggest that the young man probably did not use this bag for a sniffing practice. Because of the context (the bag placed on the head with no link around the neck), a hypoxic recreation practice remained the most probable hypothesis. Such “choking games,” including near-hangings (using various means, i.e., towel dispenser or foulard) and suffocation practices using plastic bag, are an increasing phenomenon today observed in teenager populations in most parts of the world (15–17). Indeed, these partial asphyxiation practices are popular in youngsters, especially at school. The aim is to achieve an altered level of consciousness resulting from changes in venous and arterial cerebral blood flow, and the associated rise in blood carbon dioxide tension (16). Therefore, as the myocardial sensitivity inducted by VSA may persist for hours after volatile exposure, the present fatality might have been induced by hypoxia following VSA (18). Alternatively, a loss of consciousness might have resulted from the association of VSA and hypoxia, leading to death by the persistence of hypoxia.

In conclusion, this fatality was most probably due to a VSA associated with a hypoxic recreation practice using a plastic bag. This was therefore more complicated than a “simple” “sudden sniffing death syndrome,” as sometimes seen in teenagers. This case points to the difficulties arising in VSA toxicological investigations due to issues in sample collection and preservation. Today this kind of situation is further complicated by the increase and diversification of practices, due to the availability and low cost of the chemicals.

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