A Fatal Human Intoxication with the Herbicide Allyl Alcohol (2-Propen-1-ol)

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Abstract

Oral ingestion of allyl alcohol by a 55-year-old man resulted in death within 100 min. At autopsy, bloody, reddish fluid was found in mouth, larynx, esophagus, and trachea. The mucous membranes of the trachea, stomach, and duodenum were congested and inflamed. The stomach contained a pungent green-black fluid, and all internal organs exhibited a strong pungent odor. Toxicological analysis of blood identified allyl alcohol using solid-phase microextraction and gas chromatography-mass spectrometry. Quantitative determination of allyl alcohol and its toxic metabolite, acrolein, was performed using headspace gas chromatography with flame-ionization detection. Total amounts of allyl alcohol in gastric content, bile, and urine were 3.6 g, 15 mg, and 0.5 mg, respectively. The concentration in blood was 309 mg/L. Acrolein was not detected in gastric contents and only in small amounts in bile and urine. The concentration of acrolein in blood was 7.2 mg/L. Death was attributed to acrolein-induced acute cardiotoxicity, similar to that previously documented in animal experiments.

Case History

At 9:30 a.m., a 55-year-old man was found lying unconscious on the floor after a tumbling noise was heard. A pungent odor was noticeable in the room. An ambulance was called immediately, and his stepbrother tried to resuscitate him and removed mucus from mouth and throat. An emergency doctor arrived about 10:15 a.m. and pronounced him dead. However, two ambulance workers arrived and also examined the man; they were of the opinion that the man was still alive and therefore performed extensive resuscitation. This was unsuccessful, and death was finally pronounced at 11:10 a.m.

Later it was determined that he must have opened a sealed bottle of a weed killer (brand-name Shell-Unkrauttod A, distributed by BASF, Ludwigshafen, Germany), which contained 1 L of 85% (w/v) allyl alcohol. A 250-mL volume was missing. The pungent odor noticed in the room resulted from this agent. A drinking glass was found nearby. The man was attending a dayclinic for treatment of a psychiatric illness.

Material and Methods

Chemicals

All chemicals were purchased from Sigma (Munich, Germany) and were of analytical grade except for acrolein, which had a purity of more than 90%.

Screening of body fluids for volatile compounds with solid-phase microextraction (SPME)

For blood, 1 mL was preincubated in a 10-mL crimped headspace vial at 42°C for 10 min and a 100-µm polydimethylsiloxane SPME fiber was then exposed in the headspace for 20 min. The fiber was then extracted and analyzed using GC-MS.
another 15 min. Consecutive analysis with gas chromatography–mass spectrometry (GC-MS) was performed by exposing the fiber for 10 min in the injection port of a Hewlett-Packard HP 5890 series II GC with an HP 5972 mass selective detector and an HP-1 MS capillary column (30 m × 0.25-mm i.d., 0.25-µm film thickness). The temperature of the injection port was 200°C, the temperature program started with 40°C for 4 min, 40°C/min ramp to 280°C, and 5 min final time. The mass range of the MS was 10–300 amu.

Quantitative analysis of body fluids for allyl alcohol and acrolein with headspace GC–flame-ionization detection (FID)

For analysis, 1-mL aliquots of the samples (diluted with water, if necessary) were mixed with 50 µL of the internal standard (500 mg/L 1-chlorobutane in water) in 20-mL crimped headspace vials. Analysis was performed on a PerkinElmer (Überlingen, Germany) GC 8600 with headspace autosampler HS-101. A 2-m x 1/8-in. i.d. column was packed with 0.2% Carbowax 1500 60/80 on Carbopack-C. Headspace conditions were as follows: 20-min sample equilibration at 60°C, the temperature of the needle and the transfer line was 90°C. GC conditions were 80°C initial temperature for 2 min, 10°C/min ramp to 120°C and held for 4 min, 10°C/min ramp to 150°C, and 5 min final time. Quantitative analyses were performed using linear calibration curves (all regression coefficients were greater than 0.998). Calibrators of allyl alcohol and acrolein were 0, 0.5, 1, 10, 100, 1000, and 2000 mg/L in drug-free serum for measurement in blood or in water for measurement in gastric contents, bile, and urine. The respective limits of detection (LOD), quantitation (LOQ), and linearity (LOL) were 0.5, 0.5, and 2000 mg/L for allyl alcohol and 0.5, 0.5, and 1000 mg/L for acrolein.

Results

Autopsy

The autopsy was performed four days after death. The body was refrigerated until autopsy at 4°C. At autopsy, the body weighed 98 kg and the height was 180 cm. A bloody, reddish fluid was found in the mouth, larynx, esophagus, and trachea, and the mucous membranes of trachea, stomach, and duodenum were reddened. The stomach contained 86 mL of a pungent green-black fluid and similarly the duodenum. It was found that he had suffered from ischaemic heart illness and arteriosclerosis. The heart was overall enlarged and there were scars in the wall of the left ventricle and the septum, and he had undergone two bypasses of the coronary arteries. All internal organs exhibited a strong pungent odor, external appearances of all other organs were normal (weights: brain, 1700 g; heart, 700 g; left and right lungs, 850 g; spleen, 200 g; left and right kidney, 170 g; and liver, 1500 g). Signs of the preceding resuscitation were found: in the elbow crease of the left arm and on the back of the left hand there were punctured therapeutic injection marks and ribs 2–9 were fractured on both sides.

Death could not be attributed to the pathomorphological alterations in the cardiovascular system but a lethal intoxication.

Toxicological analysis

The gastric contents were routinely tested for insecticides and some volatile compounds using the vinegar-fly Drosophila melanogaster as described previously (6,7). Ten flies were incubated in a Petri dish with a portion of the gastric contents and all died within 10 min. Further analyses of the gastric contents were performed after deproteinization with acetone with fluorescence-polarization immunosassays (FPIA, AxSym-System, Abbott, Wiesbaden, Germany) for opiates, amphetamine, cannabinoids, cocaine, methadone, benzodiazepines, and tricyclic antidepressants, and all gave negative results. In the analysis by high-performance liquid chromatography using the Remedi HS–System (Bio-Rad, Munich, Germany), only lidocaine could be detected in the gastric contents. Immunochemical screening of bile, urine, and blood gave negative results. Sulpiride could be detected only in urine with the Remedi HS-System. Acidic and basic extracts of blood were screened by GC–MS with negative results. The drinking glass was washed with 2 mL of diethylether, which was analyzed by GC–MS with negative results.

Utilizing SPME-GC–MS, ethanol and allyl alcohol were detected in blood (Figure 1). Acrolein was not detected, obviously because of poor sensitivity. For the quantitation of allyl alcohol and acrolein in blood, gastric content, bile, and urine, the headspace GC–FID method was used. The quantitative results are summarized in Table I. Ethanol was determined in blood and urine with headspace GC–FID.
Discussion

The autopsy showed no acute pathomorphological cause of death. In the toxicological analysis, lidocaine was detected in the gastric content, but it was not known whether it was administered in the course of resuscitation. The antidepressant drug sulpiride was found only in urine; therefore, its toxicological relevance in relation to the cause of death was excluded. The intake of this substance was probably part of the therapy of the psychiatric illness.

Allyl alcohol was detected in a high amount in the gastric content, indicating the oral ingestion. The exact amount of allyl alcohol ingested is not known. From the bottle, 250 mL was missing (containing 212.5 g allyl alcohol) but in the stomach only 3.6 g were left. The LD₅₀ of allyl alcohol in rats after oral ingestion is reported as 64 mg/kg body weight (8); thus the amount found in the man's body is toxic. Ethanol was also found in blood (15 mg%), but as the weed killer did not contain ethanol and no ethanol was excreted in urine, this must be attributed to putrefaction.

From the case history, the time between putative ingestion and unconsciousness was short. Allyl alcohol and acrolein were found in only minor amounts in urine and bile in comparison to the blood concentration suggesting immediate ingestion prior to death and a rapid breakdown of the circulatory function. Acrolein causes cardiotoxicity and leads to cardiac arrest in perfused rat hearts (9). Perfusion with 0.01, 0.03, or 0.30 mM acrolein was shown to produce an irregular heartbeat after 15–30 min, perfusion for another 15 min resulted in cardiac arrest. The acrolein concentration in blood of 7.2 mg/L determined in this case is equivalent to a molar concentration of 0.128 mM (molar weight of acrolein: 56.06 g/mol), which lies in the range of cardiotoxic concentrations. Therefore, the cause of death can be explained by acrolein cardiotoxicity; however, his heart/circulatory pre-existing disease may have been a predisposing factor. In addition, the time to cardiac arrest in the perfused rat hearts is in agreement with the time course of the case. The doctor was not able to palpitate the heartbeat 45 min after the man was found in his room, and death was finally pronounced as having occurred after another 55 min.

The time-course of the case and the autopsy findings are in agreement with the case report of Kononenko (5), who reported loss of consciousness in 20 min and death in 90 min. Strong irritation of respiratory tract and defects of gastric mucosa were identified, and Kononenko (5) indicated the presence of a strong mustard-like odor from the internal organs.

Specific therapy for an acute allyl alcohol intoxication has not been described. As in this case and in the case reported by Kononenko (5), the time between ingestion and lethal outcome was less than 2 h. The primary treatment effort in allyl alcohol poisonings should be to eliminate the circulating toxic metabolite acrolein. This can probably be achieved by infusion of the thiol compound N-acetylcysteine (10,11) and/or by hemofiltration (of the highly water-soluble allyl alcohol and acrolein). The further formation of acrolein may be reduced by ethanol treatment (12,13), which competitively inhibits ADH. Effective treatment with ethanol requires a concentration of 1 g/L. Primary detoxification with gastric lavage should be considered because relevant amounts of allyl alcohol could still be present in the gastrointestinal tract.

Table I. Measured Concentrations and Total Amounts of Allyl Alcohol and Acrolein in Body Fluids

<table>
<thead>
<tr>
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<th>Allyl alcohol</th>
<th>Total Conc. (mg)</th>
<th>Acrolein</th>
<th>Total Conc. (mg)</th>
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<tbody>
<tr>
<td></td>
<td>Conc. (mg/L)</td>
<td>Total Conc. (mg)</td>
<td>Conc. (mg/L)</td>
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<tr>
<td>Blood</td>
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<td>Bile</td>
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References


Manuscript received February 5, 2001; revision received May 9, 2001.