CASE REPORT

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Multiple Deaths from Argon Contamination of Hospital Oxygen Supply

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ABSTRACT: During the course of routine hospital surgical procedures, three patients lapsed into hypoxic cyanosis. Two expired immediately, another after four days of coma. Investigation of the hospital's central liquid oxygen tank revealed that it had been refilled recently and was labelled both "oxygen" and "argon." Mass spectrometric analysis of gas sampled from the questioned tank revealed a predominance of argon. A discussion of the sampling technique, method of analysis, role of the criminalist, and causes of this accident is presented.

KEYWORDS: criminalistics, gases, death, spectroscopic analysis

The role of the criminalist is often thought of as limited to certain specialty areas (that is, trace evidence, serology, drug analysis, and so forth) that pertain to the analysis of evidence collected from or related to crimes. This scope may appear to delineate the criminalist as a technician, and, as such, does not define the work of the criminalist as a "creative problem solver." Neither does it include the work of criminalists in strictly civil litigation. An example of such a somewhat atypical application is illustrated by this report which describes the role of the criminalist in the determination of a factor contributing to the cause of several hospital deaths, a determination which relates to product liability and medical malpractice and uses the skills of the forensic analytical chemist, often referred to as a criminalist. It involves the particular application of instruments and techniques available to criminalists and uses the creative-problem-solving method essential to effective criminalistics practice.

Background

Oxygen (0_2) is an essential, life-sustaining ingredient normally present in the atmosphere in a concentration of 21% [*1*]. Nitrogen (N_2), an inert gas, makes up nearly all of the remaining volume of the atmosphere. Oxygen for the respiration of anesthetized patients undergo-

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ing surgical procedures may be supplied from within the operating room or from a central oxygen supply station consisting of one or more large cylinders supplied to contain liquid oxygen and located in a restricted access area [*2*]. The cylinder manufacturer designates three different gases as appropriate for storage in the same style cylinder, with the caveat that access connections are supplied specifically for the designated gas [*3*].

Bulk liquid oxygen is supplied to hospitals from distributors who refill empty tanks from larger oxygen cylinders which, in turn, may be, refilled by distributors who produce or receive purified oxygen. Frequently, the distributors of oxygen supply other gases, such as nitrous oxide, nitrogen, hydrogen, methane, helium, and argon. The possibility of inadvertently placing the wrong gas in a cylinder is minimized by the use of fittings incompatible with other gas cylinders [*4*], painted colors [*4*], as well as labels on tanks before they are placed into use; it is not normally likely or even possible to attach an oxygen fitting to fill an argon tank or vice versa without alteration. The tank in question was labelled both "oxygen" and "argon." The pressurized gas reaches the operating room through pipes connected to the central tank(s) by noninterchangeable fittings. Gas flow is controlled by valves, also connected with agent-specific fittings.[2] An anesthesiologist mixes oxygen with inert or anaesthetic gases or both supplied to the patient in varying concentrations (within certain life-sustaining limits) [*5*].

Reported accidents involving oxygen delivery systems have included breakdown of the anaesthetic apparatus [*6*], confusion of pipelines [*6–8*], leaks [*6*], sticking regulators and valves [*6,8*], obstruction of gas flow [*6*], improper use of anaesthetic machines [*6*], confusion of connections to gases in the hospital [*6,9*], failure of the oxygen supply [*6*], and tanks filled with gases other than oxygen [*8,10,11*].

As a safety precaution against the undetected interruption of oxygen supply, the gas pressures are monitored by the anesthesiologist [*1,4,10*]. Alarms alert the operator when the oxygen pressure reaches unacceptable limits [*1*]. In addition, financially and technically feasible apparatus for oxygen monitoring [*11*] have been available for many years. Methods include chemical fuel cell reaction [*12,13*], oxygen-electrode polarography [*12,14,15*], paramagnetic detection [*16*], gas chromatography with thermal conductivity detection [*12,17*], conventional mass spectrometry [*18*], and quadrupole mass spectrometry [*19*]. Despite numerous case reports of mishaps [*7,10,11,20*] and recommendations for the use of specific oxygen detectors [*1,5,8,11,12,14,21,22*], the continuous use of specific oxygen detectors by anesthesiologists was not universal at the time of this accident.

In these particular case examples, death occurred from hypoxia in three patients who received the gas during surgery, one of whom survived comatose for four days.

Materials and Methods

Duplicate aliquots of gases from both the questioned and a known oxygen containing tank were sampled by connecting one of the outlet fittings from the bulk liquid oxygen tanks to a pipe connected to a green (the color designation for oxygen) sample tank measuring 5 in. (12.7 cm) in diameter and 13 in. (33 cm) in height which had been evacuated to a pressure equivalent to 20 in. (50.8 cm) of mercury. Next, the cylinders were transported to the laboratory where pressure gauges were attached to the sample cylinders and plumbed to connect directly to the source of a model 5985 Hewlett-Packard mass spectrometer using the direct gas inlet technique. The gauges were opened only slightly to purge air from the line and filled with gas to be analyzed. Mass spectra were monitored continuously. The spectra, which stabilized in a few seconds, were plotted after 5 min of unchanging data. Results were compared with the known mass spectra of oxygen, argon, and other commonly occurring gases.

[2] W. Saulter, personal communication, Post Welding Supply Co., Birmingham, AL, 25 May 1983.

Results and Discussion

Comparison of the fittings on the questioned tank revealed that one side of the tank had an oxygen fitting, while the other side had been modified to an argon-specific fitting. Hence, it was possible to fill the tank with argon through the modified fitting; and it was possible to attach the tank to the hospital's central oxygen supply through the oxygen fitting on the opposite side of the tank.

Mass spectrometric analysis of known oxygen (Fig. 1*a*) revealed the presence of a major molecular ion species at $m/z = 32$ as well as another species at $m/z = 16$. Other, smaller peaks were observed at $m/z = 28$, 43, and 57, which represent the presence of trace quantities of nitrogen and alkane hydrocarbon(s). Mass spectrometric analysis of the questioned gas (Fig. 1*b*) revealed the presence of a major molecular ion species at $m/z = 40$ as well as a doubly ionized species at $m/z = 20$, which are characteristic of argon. The second most prominent peak in the 0 to 57.2 m/z range was located at 32. With the smaller peak that was observed at 16, the combined results is characteristic of oxygen. Other smaller peaks were observed at $m/z = 28$, 43, and 57, which represent, as before, the presence of trace quantities of nitrogen and alkane hydrocarbon(s). The results show that mostly argon, mixed with some oxygen, was present in the questioned tank.

Three questions emerged at the center of this accident. First, why was the tank partially modified to accept argon? Second, why was the modified tank delivered to the hospital? Third, why was the absence of adequate oxygen not discovered by the hospital? Investigation showed that another customer of the compressed gas distributor, who used argon for welding, had altered the oxygen tank to accept argon in an effort to save money by using the cylinder available instead of purchasing a new cylinder. While the "oxygen" label remained on gas-use side of the tank, the word "argon" was handwritten on the opposite, liquid filling side. The distributor has filled the altered oxygen tank with argon, having the knowledge that the tank had been altered. The altered cylinder was loaded inadvertently as oxygen for

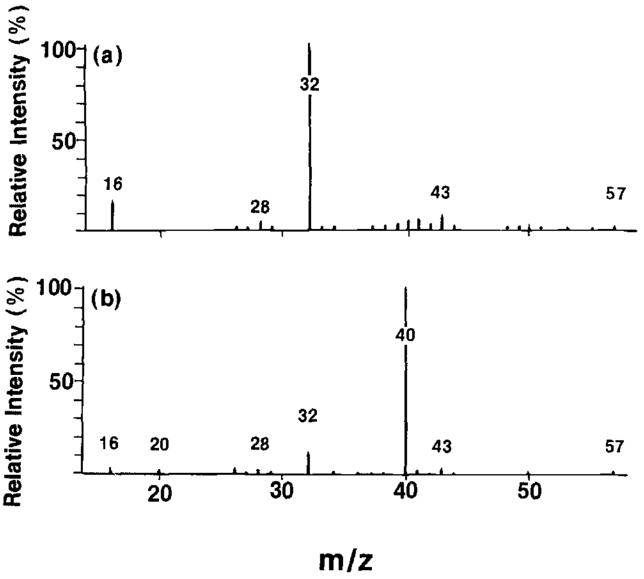

FIG. 1—*The mass spectrum of the gas sampled from a tank known to contain liquid oxygen* (a) *has prominent peaks at* m/z = *32 and 16. In* b, *the main mass spectral peak of the gas contained in the questioned tank is located at* m/z = *40.*

delivery to the hospital. Finally, the anaesthetic machine was not continuously monitored for oxygen concentration.

Professional publications cite the responsibility of the hospital [*1*], the anesthesiologist [*2,6,11,22*], and the liquid gas supplier [*8*] to guard against such mishaps. While one textbook states, "these procedures are primarily the responsibility of the hospital authorities but anesthetists should have a general knowledge of them so that appropriate precautions are observed" [*1*], another recognizes "the users dependence upon the integrity of the [liquid gas] manufacturer" [*8*]. The results of civil litigation warn practitioners that "when an accident of this type occurs, you may well be judged on the standard of practice, which is published and widely recognized even though it is not law in your area of practice" [*22*].

The responsible parties paid multimillion dollar settlements to the plaintiffs' estates. In addition, criminal charges for violations of safety requirements for labelling and handling medicinal gas were sustained against officers of the gas distributor.

Conclusion

This case report points to the combined tasks that are required for effective problem solving in forensic analytical chemistry and to an illustration of its application outside the traditional domain of criminalistics. The proper choice of sampling technique and instrumental method along with an understanding of the processes involved and a recognition of the relationship of the various data all represent assistance for forensic analytical chemist may provide to questioned death investigations. Therefore, this illustration may help define the diverse work performed by the forensic analytical chemist as it relates to questions of product liability and medical malpractice in this instance.

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