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Nitrous Oxide Exposures During Cryosurgical Procedures

Dawn Tharr, Column Editor

Case Report by William Daniels, Charles McCammon, and Lee Shands

Cryosurgery is a treatment method that uses extremely cold temperatures to destroy tissue.[1] Historically, cryosurgery has been used in a variety of procedures. One common application in use today is in the treatment of abnormal cells of the cervix.

Compressed gasses are often used to achieve the cold temperatures needed for cryosurgery. Most gases at room temperature, when allowed to expand through a valve into a lower pressure space, will cool. This is known as the Joule–Thompson effect.[2] The Joule–Thompson effect predicts that gases cool when they are allowed to expand, as when gas passes through a valve from one chamber to another. Cryosurgical instruments that use compressed gas are designed to allow the gas to expand through a valve inside the metal tip of the cryosurgical probe, causing the tip to reach extremely low temperatures. Commonly used cryosurgical gases include nitrous oxide and carbon dioxide. These gases can reach temperatures of −89°C and −60°C, respectively. Owing to its ability to reach lower temperatures, nitrous oxide is more widely used than carbon dioxide for cryosurgical applications.

Nitrous oxide has been widely studied as an anesthetic gas in medical, dental, and veterinary procedures. In a 1977 criteria document, the National Institute for Occupational Safety and Health (NIOSH) stated that studies had suggested that chronic exposure to anesthetic gases increased the risk of both spontaneous abortion and congenital abnormalities among female workers and wives of male workers. The information available to support conclusions on reproductive effects resulting from exposure to nitrous oxide alone were not felt to be definitive. However, NIOSH felt a degree of concern should be associated with such exposures. The NIOSH recommended exposure limit (REL) for nitrous oxide is 25 ppm during the period of administration.[3] The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value (TLV) of 50 ppm as an 8-hour time-weighted average (TWA).[4]

Facilities Surveyed

Environmental evaluations of cryogenic procedures were conducted at two facilities which used nitrous oxide as a cryogenic gas. At Facility 1, the cryosurgical instrument used a single, 20-pound, "D"-type nitrous oxide cylinder. The surgical instrument consisted of a cylinder valve and a console that contained a tank pressure gauge and a connection for the cryogenic probe. The cryogenic probe consisted of a length of high-pressure tubing, a dual trigger mechanism, the metal probe tip, and tubing to return the gas to the console. One of the triggers allowed the gas to flow through the tip of the probe creating the freezing action. A defrost trigger also stops the flow of gas in the probe tip causing the tip to defrost. An exhaust port was located beneath the console of the instrument for attachment to a vacuum or exhaust system; however, this was not in use during the period of this survey. The procedures were carried out in an examination room measuring 8.5 by 11 feet with an 8-foot ceiling. The room was provided with an estimated 5 air changes per hour (ACH).

At Facility 2, the cryosurgical instrument was similar in design except that the instrument used two "D"-type cylinders connected by a manifold, with the on/off control for the gas located on the instrument console. In addition, no exhaust port was present on this instrument. The gas exited the machine through four small holes at the base of the probe. Procedures were carried out in an examination room measuring 12 by 9 feet with an 8-foot ceiling. The room was provided with an estimated 7 ACH.

The amount of nitrous oxide used during the cryosurgery procedures varied with the facilities, practitioner, the size and type of tissue being frozen, and the cryogenic instrument being used. At Facility 1, a freeze–thaw–freeze technique was generally employed. Freeze times ranged from 1.5 to 4.5 minutes, with approximately 10 minutes between freezes. At Facility 2, a single freeze application was used. Freeze times were reported not to exceed 5 minutes under most circumstances.

Methods

Environmental surveys were conducted at the two facilities to determine the extent of exposure to nitrous oxide during cryosurgery procedures. Cryosurgery procedures were simulated at each facility according to either the observed or reported work practices.

Measurements of nitrous oxide were made using a portable infrared analyzer with a sampling probe located in the approximate position of the practitioner's breathing zone. In order to measure the high concentrations of nitrous oxide expected, the analyzer was set to a secondary absorption wavelength of 7.66 μm, a pathlength of 0.75 M, and a slit length of 1 mm. The instrument was calibrated on site for nitrous oxide between the range of 0 and 20,000 ppm using a closed loop calibration system. The analyzer was attached to a datalogger to record readings at 10-second intervals.

Results

Figure 1 shows the concentrations of nitrous oxide during a simulated procedure at Facility 1 that used a 4-minute freeze, followed by an 8-minute thaw, followed by a 3-minute freeze. Peak concentrations of nitrous oxide exceeded 17,000 ppm. The 25-minute TWA concentration for this procedure was 7500 ppm. This exceeded the NIOSH REL of 25 ppm for the duration of the procedure. Assuming no other exposure to nitrous oxide occurred during the day, the calculated 8-hour TWA exposure would be 390 ppm, which would exceed the ACGIH TLV of 50 ppm as an 8-hour TWA.

Figure 2 shows the concentration of nitrous oxide during a simulated procedure carried out at Facility 2 using a single 5-minute freeze. Peak nitrous oxide concentrations exceeded 13,000 ppm. The calculated 15-minute TWA was 4000 ppm, which would exceed the NIOSH REL of 25 ppm. Assuming no additional exposure during the day, the calculated 8-hour TWA would be 130 ppm, which would exceed the ACGIH TLV of 50 ppm as an 8-hour TWA.

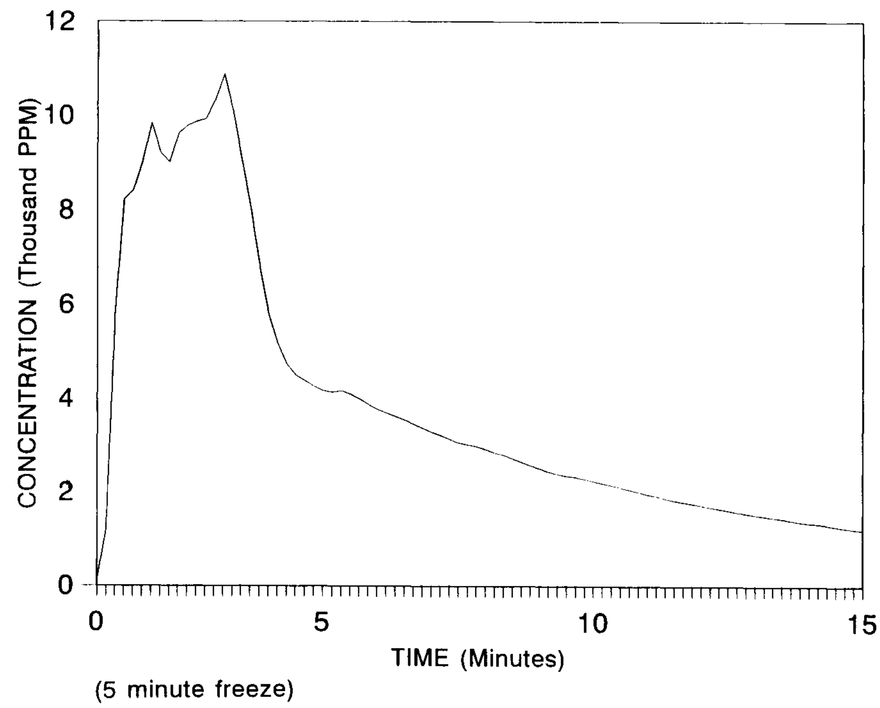

FIGURE 2. Nitrous oxide concentrations at Facility 2.

Nitrous oxide was also found to migrate into adjacent areas of the facilities. During two cryosurgery procedures at Facility 1, concentrations of 195 ppm and 140 ppm were found in 30- and 25-minute bag samples collected at a nurses' station located a short distance from the examination room.

Concentrations of nitrous oxide were also found to remain elevated in the examination rooms well after the cryosurgical procedures were finished. Measurements taken in an examination room 70 minutes after an actual cryosurgical procedure in Facility 1 showed the concentration of nitrous oxide still remained above 25 ppm. This would further contribute to the exposure of the personnel using the examination room for subsequent procedures.

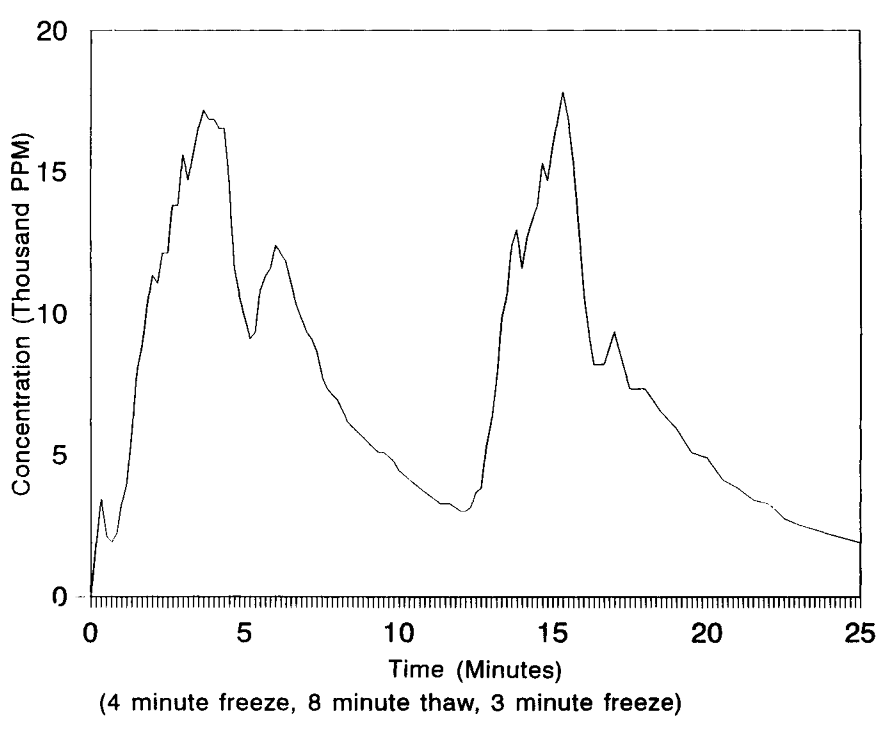

FIGURE 1. Nitrous oxide concentrations at Facility 1.

Conclusions and Recommendations

Several factors can affect the concentration of nitrous oxide during cryosurgery procedures. These include the use of local exhaust ventilation, the duration of nitrous oxide use, the nitrous oxide tank pressure, the size of the room, and the effectiveness of the general ventilation. The results of the environmental survey show that short-term exposures to nitrous oxide can be extremely high during unvented cryosurgery procedures. The use of local exhaust is the most practical means of reducing these exposures. Except for the possibility of minor leakage around connections and fittings, this would effectively remove all of the nitrous oxide used in the procedures.

The cryosurgical unit used in Facility 1 was equipped with an exhaust port that could be easily attached to a room vacuum or other local exhaust ventilation system. The cryosurgical unit at Facility 2 was an older design (1973) which was not equipped with a scavenging port; however, discussions with the manufacturer indicated that the unit could be retrofitted to allow for direct attachment to an exhaust system.

At the two facilities surveyed, cryosurgery procedures were reportedly carried out infrequently (approximately one procedure every week or two). However, based on the magnitude of the exposure coupled with potential reproductive effects associated with nitrous oxide, it would be prudent to reduce exposures as much as possible. The use of local exhaust with cryosurgical instruments would greatly reduce the exposures to nitrous oxide and minimize any risk of adverse health effects to the employees carrying out these procedures.

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