

2. Moore DC, Bridenbaugh LD: Spinal (subarachnoid) block: A review of 11,574 cases. *JAMA* 195:907-912, 1966
3. Thorsen G: Neurological complications after spinal anesthesia and results from 2,493 follow-up cases. *Acta Chir Scandinav* (suppl 121) 95:1-272, 1947
4. Goldman WW, Sanford JP: An "epidemic" of chemical meningitis. *Am J Med* 29:94-101, 1960
5. Seigne TD: Aseptic meningitis following spinal analgesia. *Anesthesia* 25:402-407, 1970
6. Feigin RD, Shackelford PG: Value of repeat lumbar puncture in the differential diagnosis of meningitis. *N Engl J Med* 289: 571-574, 1973
7. Varki AP, Puthursan P: Value of second lumbar puncture in confirming diagnosis of aseptic meningitis. *Arch Neurol* 36: 581-582, 1979
8. Austin DA, Sokolowski JW: Postlumbar puncture chemical meningitis. *NY J Med* 68:2444-2446, 1968
9. Gibbons RB: Chemical meningitis following spinal anesthesia. *JAMA* 210:900-902, 1969
10. Hurst EW: Adhesive arachnoiditis and vascular blockage caused by detergents and other chemical irritants: An experimental study. *J Pathol Bacteriol* 70:167-178, 1955
11. Denson JS, Joseph SI, Koons RA, Murry WE, Bissonnette HW: Effects of detergents intrathecally. *ANESTHESIOLOGY* 18: 143-144, 1957
12. Joseph SI, Denson JS: Spinal anesthesia, arachnoiditis, and paraplegia. *JAMA* 168:1330-1333, 1958
13. Nicholson MJ: Aseptic meningitis following spinal anesthesia. Case report. *Anesth Analg* 43:370-372, 1964
14. Kilpatrick ME, Girgis NI: Meningitis—a complication of spinal anesthesia. *Anesth Analg* 62:513-515, 1983

Anesthesiology
62:677-678, 1985

Errors in Installation of a New Gas Delivery System Found after Certification

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Bulk supplies of oxygen and nitrous oxide frequently are delivered via pipelines to operating rooms. Stringent standards have been formulated for the installation of central gas supply systems by the National Fire Protection Association (NFPA).‡ Certification of newly installed systems by an engineering firm is a common practice, most often on a voluntary basis by the hospital. In many states, evidence of satisfactory specifications is required for licensure of the hospital facility. The Joint Commission on Accreditation of Hospitals and most insurance companies require an inspection to verify compliance with published standards.

Errors during installation can lead to crossed medical gas and vacuum pipelines, leaks in the pipelines or

concealed connectors, contamination of delivered gas by other gases, water, hydrocarbons, or particulate matter.¹ Pressures may exceed or fall below designed limits and must be monitored by sensitive alarm systems. The adaptors that connect piped gases to the machine may be installed with improper fittings or reversed. Several of these problems have resulted in patient deaths and have been addressed in publications.¹⁻⁴

The present report describes errors detected 6 weeks after certification of the gas delivery system in a new operating room suite by an engineering firm.

REPORT

In mid-February, 1984 a new patient care facility was nearly complete. The operating room suite contained preassembled quick-connect Chemetron® gas delivery system with ceiling-mounted hose reels. Over the next 3 months, construction continued with interim inspections by an engineering firm. A number of gas leaks and alarm system deficiencies were noted and corrected. On June 14, 1984, all medical gases and vacuum systems were certified as satisfactory. After that date, the contractor remained on site, completing ceiling roentgenographic installations and mounting stainless steel cover plates in the ceiling, through which the gas hoses and connectors were passed.

On July 29, 1984, one day prior to move-in, the Anesthesiology Team conducted a final inspection to verify the integrity of gas lines, identity of the delivered gases, and proper function of connectors. Three defects were found in 14 operating rooms. A vacuum outlet was inoperative due to particulate matter in a check valve. An oxygen port to a cardiopulmonary bypass location delivered no gas at all. Subsequent dismantling of the pipe-interface in the ceiling revealed an absent spring device in a check valve. In a third room,

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Received from the Department of Anesthesiology, Albert Einstein Medical Center, Northern Division, Philadelphia, Pennsylvania, and ECRI, Plymouth Meeting, Pennsylvania. Accepted for publication December 13, 1984.

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Key words: Anesthetic, gases: nitrous oxide. Oxygen: delivery systems.

‡ NFPA 56F: Nonflammable Medical Gas Systems, National Fire Protection Association. Batterymarch Park, Quincy, Massachusetts 02769, 1979.

another discovery was made. The oxygen hose was found to have a female Chemetron® nitrous oxide fitting connected to it. Similarly, the Chemetron® female oxygen connector was attached to a nitrous oxide hose. After documentation of the improper attachments was made, the fittings were removed immediately by hand without difficulty, exchanged to the proper configuration, and marked with a surface sealant. Retesting every gas hose in the operating suite except two labeled "carbon dioxide-oxygen" verified proper pressures, composition, and alarm sensitivity before the first anesthetic was administered. A later analysis of the carbon dioxide-oxygen gas mixture revealed 100% CO₂. Pure CO₂ had been attached to the delivery carbon dioxide-oxygen pipes at the bulk gas location outside the hospital. This "carbogen" mixture never had been used by the cardiac perfusionists and was probably an unnecessary gas line installation.

DISCUSSION

This is the second report of crossed connections of medical gas lines with Chemetron® quick-connect hose couplers. § In the first incident, the crossed connections resulted in the deaths of two patients. ¶ In both, the factory-assembled female couplers for nitrous oxide and oxygen had been unscrewed at their threaded fittings to the gas supply hose and reversed during reassembly.

In this instance, the contractor subsequently admitted that in rooms lacking the stainless steel ceiling cover plate, every female gas coupler had been removed temporarily from its respective hose, as the connector was too large to pass through the aperture in the plate. Improper replacement of the couplers led to the crossed connections, which were detected prior to use of the operating room equipment.

Threaded fittings on the back of Chemetron® and other manufacturers' quick-connect couplers are interchangeable with a variety of gas hoses, including oxygen, vacuum, nitrous oxide, air, and carbon dioxide. Thus, the potential for crossed connections exist, and even though the coupler face plates are color coded, accidental attachment to an anesthesia machine may result. Furthermore, even correct initial attachment might be followed by subsequent improper connection, as a survey of the remaining 160 couplers revealed 13 that could be loosened by hand. Factory-attached fittings originally are tightened to 230 in-lbs and cannot be unscrewed by hand but they must be disassembled to pass through the cover plate. Contractors, hospital administrators, and anesthesiologists must be aware that gas composition, flow rates, and pressures must be tested at the endpoint of the gas delivery system. Checking at some point prior to the fresh gas outlet of the anesthesia machine, venti-

lator, or pump oxygenator provides no security that the entire delivery system is delivering proper oxygen, nitrous oxide, vacuum, or carbon dioxide-oxygen.

RECOMMENDATIONS

The following measures are recommended:

1) Manufacturers should construct fittings for all connectors that are different for each type of gas. Connectors should not be removed easily by hand or with simple hand tools.

2) All threaded connections should be marked with a surface sealant such as Glyptol® to indicate any tampering. Also, all connectors and hoses must be color coded correctly.

3) Any interim inspections by engineering firms are invalidated by subsequent disconnections by a contractor. All work must be completed before the final inspection is done.

4) Regardless of the reassurance offered by construction personnel and reputable engineering firms, there is no substitute for vigilant testing and documentation of gas identification and testing at the endpoint of the delivery system by the Anesthesia Team prior to clinical use of the system. The medical gas system also should be inspected periodically to reveal any mechanical problems.**

5) Whenever any part of a medical gas system is modified or serviced, the Anesthesiology Department should be alerted so that inspection can be carried out before the system is put in service. Any untested portions of the system should be labeled prominently by taping over each outlet as a warning.

6) An oxygen analyzer with tested alarm system in the breathing circuit always should be used during anesthesia in which gases are delivered to patients.

7) The Anesthesiology Department should be involved in all phases of medical gas system planning to select appropriate gas mixtures and safe coupling systems.

REFERENCES

1. Dorsch JA, Dorsch SE: Understanding Anesthesia Equipment, Construction, Care and Complications, second edition. Baltimore, Williams and Wilkins, 1984, pp 16-37
2. Feeley TW, Hedley-White J: Bulk oxygen and nitrous oxide delivery systems: Design and dangers. *ANESTHESIOLOGY* 44: 301-305, 1976
3. Eichhorn JH: Anesthetic considerations in setting up a new medical facility, *International Anesthesiology Clinics* 19, #2, Boston, Little, Brown and Co, 1981
4. Feeley TW, McClelland KJ, Malhotra IV: The hazards of bulk oxygen delivery systems. *Lancet* 1:1416-1418, 1975

§ Health Devices 13, #9: Hazard-crossed connections in medical gas systems. July 1984, p 221-222.

¶ Biomed Safety Standards 14: Legal Actions: Cross-connected anesthesia supply lines allegedly result in two deaths; negligence suits filed. vol. 14, no. 2, February 15, 1984, pp 15-16.

** Health Devices 13 #9: Inspection and Preventive Maintenance of Medical Gas/Vacuum Systems, July 1984, pp 227-230.