

Xe-133 Rebreathing System for Ventilation Studies on Ventilator-Assisted Patients

Ernest J. Wiesen, Stefan D. Miron, and Errol M. Bellon

Cuyahoga County Hospital, and Case Western Reserve University School of Medicine, Cleveland, Ohio

We describe a manually operated system, simple to assemble, that will enable xenon-133 lung ventilation studies to be performed on ventilator-assisted patients. It can be constructed from items readily available. Radiation exposure levels to the operator were measured and are reported.

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Patients on respirator-assisted ventilation present problems in that the xenon-133 rebreathing system normally used for lung ventilation studies has no provision for assisting ventilation, so that a scintigram in rebreathing or equilibrium mode cannot be performed. Additionally, there is no satisfactory way to collect and dispose of the xenon-133, as required by regulations of the Nuclear Regulatory Commission (NRC). A system or device is needed that would (a) maintain ventilator-assisted respiration; (b) permit performance of all phases of a ventilation study (1,2); and (c) allow simultaneous collection of all of the radioactive gas for safe disposal.

Such a system has been in use in our laboratory for two years. Since then, devices with this capability have been described in the literature (3) and are available commercially.* The major advantage of the device presented here is its simplicity, ease of construction, and a construction cost of less than \$100.00.

SYSTEM DESCRIPTION (Fig. 1)

The heart of the system is a common AMBU bag. This is slightly modified by gluing a plastic tube to the outlet port to accommodate a standard breathing air-hose connection. A rotary valve assembly is used to switch from the rebreathing to the washout mode. The valve from a disposable xenon system† is used, but it must be modified. The rubber membrane valves are removed from the two ports that have the membrane valves, and one is then plugged with a stopper (it makes no difference which one is plugged). The remainder of the system consists of a commercial xenon-133 rebreathing system.‡

The assembly of the device starts with the rebreathing system† (Fig. 1). The Y-shaped valve normally connected to the mouth-piece of the rebreathing system is removed and replaced by the modified AMBU bag. The manual valve, a "T" adapter normally supplied, is replaced by the modified rotary valve. This valve is

inserted by connecting the breathing hose from the AMBU bag to the port around the center of the large-diameter body of the rotary valve (Fig. 1). The oxygen supply is connected to the oxygen inlet connection of the AMBU bag. The 12-liter bag normally supplied with the rebreathing system is replaced by the 30-liter bag from the disposable system.† The CO₂-absorber cartridge is filled with soda lime. More detailed construction and assembly instructions will be sent on request.

OPERATION OF SYSTEM

The flow of oxygen is adjusted for 2 to 3 l/min and the rotary valve turned to rebreathing mode. The system currently providing ventilation is disconnected from the endotracheal tube and the modified system's AMBU bag is connected. The AMBU bag is manually operated as it normally would be, and the patient is stabilized on the system for about 30 sec. The xenon-133 is injected through a needle inserted into the rubber membrane port of the rotary valve, and data acquisition is started. The AMBU bag is operated in the normal manner, and images are obtained until equilibrium is reached and the final equilibrium image is obtained. The washout phase is started by turning the rotary valve to allow room air to enter the system; this stops the flow from the 30-l bag, causing it to fill slowly during this phase. The patient is kept on the system until the washout phase is completed. The patient is then disconnected from this system and reconnected to the original one. The xenon-133 must be disposed of as required by the institution's NRC license.

RADIATION EXPOSURE

During the ventilation study nonradiation workers will be operating the AMBU bag. To ensure that radiation exposure is below the legal limit for a nonradiation worker, a model was constructed using a balloon to simulate the lung. The radiation geometry of patient and operator were simulated as closely as possible. Most of the exposure occurs during the rebreathing phase, when the xenon-133 recirculates through the AMBU bag. Once washout

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For reprints contact: Ernest J. Wiesen, BSEE, Dept. of Radiology, Cuyahoga County Hospital, 3395 Scranton Rd., Cleveland, OH 44109.

REBREATHING SYSTEM

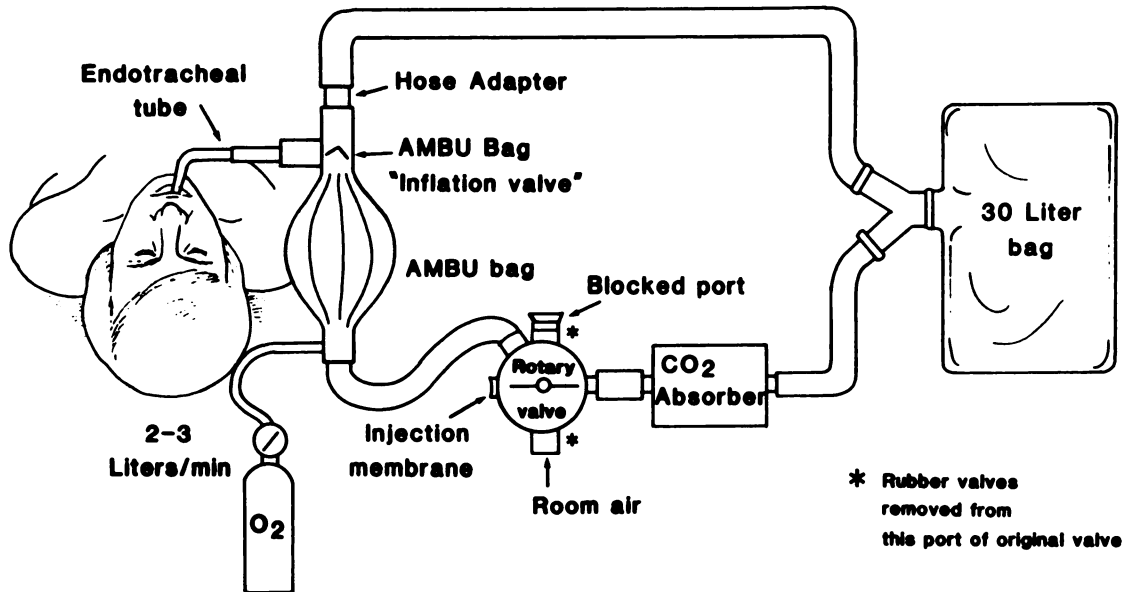


FIG. 1. Diagram of Rebreathing System. See text for construction and operation.

TABLE 1. RADIATION EXPOSURE

Organ	Exposure
Hands	.095 m R/min*-mCi
Forearms	.036 m R/min-mCi
Body	.025 m R/min-mCi

* Time refers to rebreathing time.

starts and room air enters the system, the AMBU bag contains room air and exposure to the operator is greatly reduced, being no greater than with a normal xenon-133 study. The radiation exposure was measured using an ion chamber and thermoluminescent dosimeters attached to the operators hands. The results are shown in Table 1. The rates shown are the maximum rates, for as more oxygen enters the system, the exposure rate is decreased. To estimate total exposure, one multiplies these rates by the injected dose and the length of time between injection of the xenon-133 and the switching of the valve to room air, the rebreathing phase. A typical radiation dose to the operator's hands when using 20 mCi (740 MBq) of xenon-133 and a 2-min rebreathing mode, is about 4 mrad (40 μ gray). For comparison, this roughly equals the radiation dose to the middle of the index finger received in holding an unshielded 2-cc syringe containing 20 mCi (740 MBq) of Tc-99m for 15 sec (4).

DISCUSSION

The system has been used on patients with few difficulties and excellent results. The major problem encountered earlier was the

complete filling of the 12-liter bag, originally supplied, before the study was completed, but the larger capacity of the 30-liter bag eliminates it. The system is cleaned, discarding the soda-lime, and gas sterilized to be reused.

FOOTNOTES

* Diversified Diagnostic Products, Inc., 7007 Britmoore #15, Houston, TX 77041.

† E-Xe-BREATHE, Nuclear Associates, 100 Voice Rd., Carle Place, NY 11514.

‡ Atomic Products Corporation, PO Box 657, Center Moriches, NY 11934.

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