An Improved System for Administration of ^{133}Xe in Pulmonary Ventilation Scintiphotography

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The increase in use of ^{133}Xe ventilation studies for the evaluation of pulmonary disease has led to the need for an inexpensive, functionally simple, closed system for administration of the ^{133}Xe gas and maintenance of patient gas exchange for prolonged periods of time in an effort to gain multiple high-count, high-resolution images. A number of systems are currently available commercially or are described in the scientific literature. Most of these systems use a spirometer or a meteorological balloon as a rebreathing reservoir. Although it is easier to control the dilution volume in the spirometric devices, one is still dealing with a relatively large dilution-type reservoir in relationship to patient tidal volume. A disadvantage of either system is the problem of patient cross contamination and the difficulty in cleaning. Disposable mouthpieces and hoses can generally be used with any available system, but the reservoirs, which are very likely to be contaminated due to condensation of moisture from patient respiration, are not designed to be disposable. Although for the most part ventilation studies are done for evaluation of pulmonary emboli, with the advent of the computer to nuclear medicine, regional ventilation-perfusion (v-q) ratios may be a valuable adjunct for the evaluation of patients with chronic obstructive lung disease and even active pulmonary disease. In this situation, of course, a totally disposable system would be invaluable.

The System

With these things in mind, we have put together a system based on a disposable anesthesia circuit commercially available as two components. The first component is a prepackaged and sterile flexible breathing hose and bag. The second component is a prepackaged plastic canister containing CO_2 absorbent crystals and a cross-valve assembly (Fig 1).

The breathing hose and bag are supplied in one package*. The breathing hose contains a Micropore filter on the inspiratory side which serves as a bacterial filter, making it possible to reuse the CO_2 absorbent canister. There is a swivel "Y" connector at the patient end of the hose circuit. The rebreathing bag has a volume of 3 liters which approximates the mean inspiratory capacity of the average male or female. The plastic canister† containing soda lime crystals for absorbing CO_2 has two gas inlets on the back. We use one to add ambient air and the other for metering in oxygen.

When properly attached to the system, the cross-valve assembly on the canister directs the flow of gases to form a circuit-breathing system. This is done by two flutter valves which direct the expired gas into the rebreathing bag and, on inspiration out of the bag, across the CO_2 absorbent crystals, through the Micropore filter, up the inspiratory side of the circuit, and into the patient. This then forms a closed-circuit breathing system.

An appropriate mouthpiece is attached to the swivel "Y" connector located at the patient end of the circuit. A wide variety of mouthpieces or breathing masks are available. At our institution, a Bennet-seal‡ mouthpiece has been suitable for most patients; however, in children and in edentulous patients occasionally a Bennett positive pressure mask is used. The Bennett-seal mouthpiece (or the mask) is attached to the swivel "Y"

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* Ohio Medical Products, Division of Air Radiation Company Inc, Madison, Wis

† Dryden Corp., 5835 N Tacoma Ave, Indianapolis, Ind 46220 (Mod #110–011)

‡ Puritan Bennett, Oak at 13th St, Kansas City, Mo

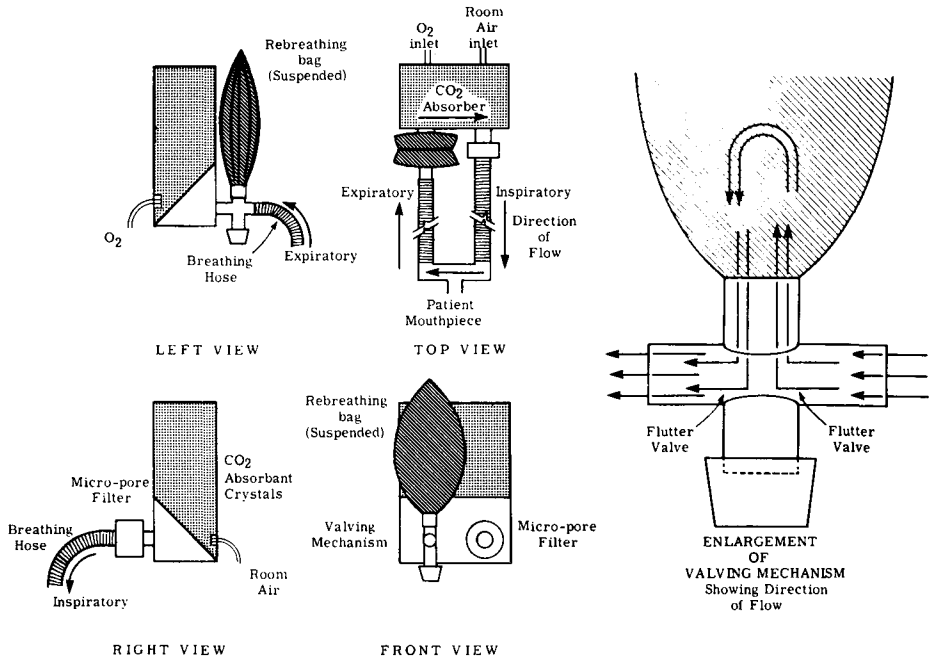

FIG. 1. Schematic drawing of system showing various parts, their location, and function within system.

connector by a disposable 5-in. flexible breathing hose *. This hose is also supplied with a mouthpiece which fits into the Bennett-seal device. These components are commonly used by respiratory therapy in the administration of intermittent positive pressure breathing therapy.

In actual operation, the circuit is modified slightly to provide more effiicent utilization of the available xenon since the ultimate goal of the system is increased concentration of xenon within the patient. This is accomplished by inverting the entire system to take advantage of the high specific gravity of xenon and cause a pooling of ^{133}Xe at the level of the inhalation ports in the canister and also at the connector end of the breathing bag next to the cross valve mechanism. By doing this, the rebreathing bag is no longer suspended by the connector; therefore, a minor modification of the canister holder † (which incidentally is available from the same supplier as the canister itself) is necessary (Fig. 2). A ¼-in. stainless rod bolted to the base of the canister holder and bent to curve over the canister with a hook on the end, suspends the bag very nicely. An alligator clip is placed on the hook and clipped to the end of the bag and is supported by a spring to compensate for the expansion and contraction of the bag during respiration.

At the beginning of the procedure, the bag is filled with room air, establishing a 20% oxygen mixture. This is accomplished by using a small air pump connected to one of the gas inlets on the back of the canister. Oxygen is metered into the circuit only to replace that oxygen which is used by the patient under normal respiration during the course of the study. The average individual

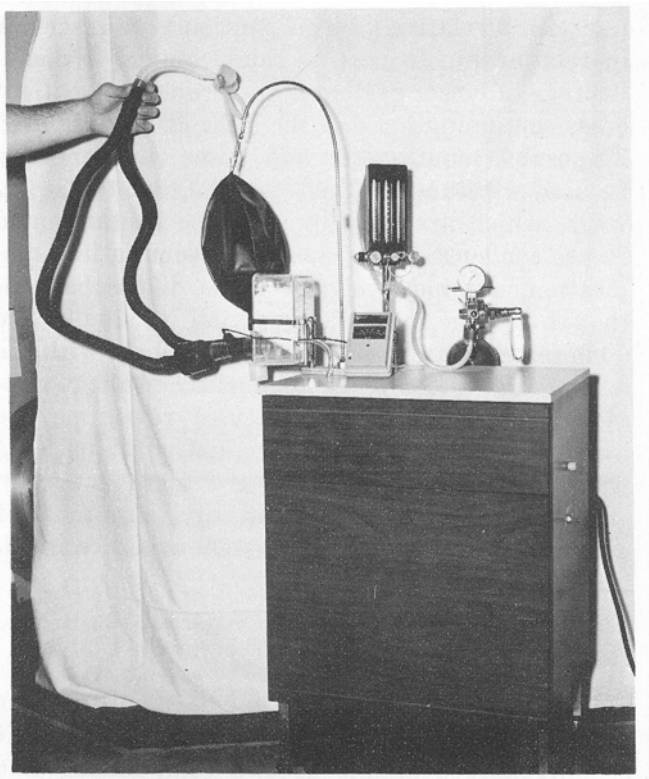

FIG. 2. Assembled system as used at Indiana University Medical Center. System is mounted on modified patient bedside table.

* Bard-Parker, Div of Becton, Dickenson and Co, Rutherford, New Jersey

† Dryden Corp, 5835 N Tacoma Ave, Indianapolis, Indiana 46220 (Mod #111–001)

Advantages of the System

1. EASE OF OPERATION
   - No complicated hook up to gamma camera
   - No set sequence to follow
   - Choice of style of ^{133}Xe administration
   - No internal parts to disassemble or clean
2. PATIENT PROTECTION
   - Disposable—No sterilization
   - Virtually no cross contamination
   - Can be used on patients with active disease
3. COST

Dryden canister $6.10–20 pt. supplied with valve	$0.31
Breathing bag and hose assembly	2.67 ea
Mouthpiece and tubing	.02
Cost per patient	$3.00

at rest uses approximately 250–350 cc/min of oxygen. We have found that using room air concentrations of oxygen allows us to use this system on patients with long-standing chronic obstructive lung disease without danger of inducing CO_2 narcosis. To further facilitate the control of these concentrations, we have added to the circuit an optional oxygen concentration monitor * placed on the inspiratory side of the circuit, thus allowing constant monitoring of the concentration of oxygen in the inspired gas.

After the patient study is completed, the system is flushed with room air by manually filling and deflating the bag for a minimum of four times. This is done either simultaneously or immediately after the patient washout portion of the study. The breathing hose, the rebreathing bag, and the canister have been checked for residual activity after flushing, and it has been determined that less than 1% of the administered dose is found at any time anywhere within the system. It can therefore be safely assumed that the system components do not collect or hang-up the ^{133}Xe.

In our monitoring studies, we have detected no free xenon in the vicinity of the system that would indicate that the xenon is penetrating the rubber bag. We also have observed very stable counting rates on the gamma camera during the course of the study which would also support this finding. The washout and flushing are accomplished by the venting of the system and the patient into a 4-in. flexible breathing hose attached to the hot lab fume hood. Assuming ten ^{133}Xe ventilation studies per week, the volume of air moved through the vent hose and the continuously operated fume hood is sufficient to reduce the average weekly ^{133}Xe concentration at the hood exhaust point to 8×10^{-7} μCi/cc. Since the hood exhaust is located on the roof of the hospital, it is safe to assume additional air dilution sufficient to assure that no individual is continuously exposed to ^{133}Xe gas concentrations in excess of the 3×10^{-7} μCi/cc maximum permissible concentration for unrestricted areas specified by the Atomic Energy Commission in its regulation 10 CFR 20*. For those without this facility, the system is readily adaptable to the use of commercially available xenon traps † or the use of a large-volume meteorological-type balloon as a collecting reservoir by using a one-way breathing valve and allowing the patient to breathe in ambient air and expire into the balloon and then venting the balloon outside the facility into the air. These are all alternative methods for safe disposal of ^{133}Xe, providing appropriate calculations and/or measurements are made to document compliance with the AEC protection standards.

Technologist exposure during the ^{133}Xe procedure is being evaluated as part of a continuing TLD monitoring program in our laboratory. Preliminary data indicate the total-body exposure from this procedure is less than 20 mR/month and the hand exposure is approximately 100 mR/month. It should be noted that the technologist injected the ^{133}Xe during these exposure studies. The apparatus could be provided with shielding, but this appears unnecessary.

Summary

In summary, the features of compactness, ready availability of components, simplicity of use, the increased ^{133}Xe activity within the patient, and the safe prolonged maintenance of the patient on the system, regardless of the disease state, has made possible the routine performance of multiple view, high-resolution, high-count ^{133}Xe ventilation studies and placed them in the realm of routine nuclear medicine pulmonary examinations.

* Sensor Labs, A Division of Instrumentation Laboratories, 113 Hartwell Ave, Lexington, Massachusetts 02173 (IL 406)

* Code of federal regulations, title 20, part 20, Standards for Protection Against Radiation

† I. E. Mod, Ye 102, Atomic Development Corp, 7 Fairchild Court, Plainview, New York