Y-connector (fig. 2, *V*)—preferably close to the patient. In this location the diaphragm is inflated through a small-bore tube (*T*) attached to the inspiratory port at the ventilator housing via adaptor (*E*).

The entire circuit we prefer is shown in figure 2. The inspiratory circuit includes the heated humidifier (*H*) and a device which automatically collects and dumps condensed water (*D*). Tidal volumes are monitored intermittently by a Wright ventilation meter connected to the expiratory port of the exhalation valve (*V*).

We have successfully used prototypes of this valve in our Intensive Care Unit for several months. This relatively minor improvement results in safer, more flexible application of the Emerson ventilator and reduced repair and maintenance costs. Additionally, the valve, with minor modifications, has proved to be a good exhalation valve with other types of IPPV assistor–controller ventilators of both pressure- and volume-cycled types, provided there is a Y-piece at the patient's airway and the valve is inserted into the exhalation line coming from the Y-piece.

Comparison of Spinal and General Anesthesia for Lower Abdominal Surgery in Patients with Chronic Obstructive Pulmonary Disease

MARK B. RAVIN, M.D.*

There is no general agreement as to the anesthetic technique best suited for patients with chronic obstructive pulmonary disease who are to have lower abdominal operations. This study was undertaken to provide objective evidence which would help decide this issue. Serial values of arterial blood *p*H, P_{O_2}, and P_{CO_2} of patients who had general anesthesia were compared with these values in patients who had spinal anesthesia.

METHODS

Twenty-six male patients with histories of emphysema, scheduled for elective lower abdominal surgery (inguinal herniorrhaphy, suprapubic prostatectomy, hydrocelectomy), were screened for study (table 1). To confirm the presence of chronic obstructive pulmonary disease and to evaluate its severity, a slight modification of the criteria of Paskin *et al.*[1] was used. We reviewed each patient's medical history, electrocardiogram, and posterior–anterior and lateral roentgenograms of the chest. Pulmonary function studies were then performed with the patient in a sitting position (table 2).[2,3] Predicted values, corrected for age, were obtained from the tables of Berglund *et al.*[3] Only those 20 patients whose MVV's were less than 60 l/min and whose RV/TLC values were greater than 45 per cent were accepted for study. None of the patients was able to perform the "match test."[4] Heparinized arterial blood samples were drawn with the patient supine, at rest, breathing air. Blood gas tensions ($P_{a_{O_2}}$ and $P_{a_{CO_2}}$) and *p*H were measured with appropriate electrodes at 37 C.

On the day of operation, all patients received secobarbital (1.0 mg/kg body weight) and atropine (0.5 mg) intramuscularly 40–65 minutes prior to induction of anesthesia. General or spinal anesthesia was assigned by a random card-shuffling technique, with ten patients in each group.

General Anesthesia. General anesthesia was induced by intravenous injection of a 2½ per cent solution of sodium thiopental (average dose 175 mg, range 50 to 350 mg) to an endpoint of elimination of the eyelash reflex. The

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TABLE 1. Physical Characteristics of Patients Anesthetized by Spinal or General Anesthesia

	Age (years)	Height (inches)	Weight (kg)	Body Surface Area (m^2)	Operating Time (min)
Spinal anesthesia (n = 10)					
Mean	70.8	66.5	72.6	1.83	68.5
±SD	7.2	4.0	7.7	1.50	21.4
General anesthesia (n = 10)					
Mean	70.1	67.1	71.3	1.83	61.5
±SD	5.8	5.0	7.8	1.80	26.3

patient was given succinylcholine (80 mg iv) and the trachea was intubated with a cuffed endotracheal tube. Anesthesia was maintained with halothane (0.5–1.2 per cent) which was delivered in a nitrous oxide–oxygen mixture (N_2O, 3 liters; O_2, 2 liters). Respiration was assisted during the operation with periodic manual hyperinflation of the lungs. Muscle relaxation, when necessary, was achieved with an intravenous drip of a 0.1 per cent solution of succinylcholine (maximum dose, 375 mg).

Spinal Anesthesia. All patients assigned to the spinal anesthesia group received 50 mg of ephedrine intramuscularly five minutes prior to the injection of the anesthetic agent. Spinal anesthesia was achieved with a mixture of 1 per cent tetracaine HCl and an equal volume of 10 per cent dextrose, introduced via a 25-gauge needle with the patient in a sitting position. The dosage chosen (11–16 mg) was based on the patient's height, as outlined by Dripps *et al.*[5] for xiphoid levels of anesthesia. Actual sensory levels, as tested by responses to pin prick, ranged from T11 to T6. Blood pressure was maintained within 20 per cent of the preoperative level by the administration of Ringer's lactate solution. Throughout the operation the patient inhaled a mixture of 40 per cent oxygen and 60 per cent nitrogen, administered through a close-fitting mask via a semiclosed carbon dioxide-absorption system. No other inhalation or intravenous supplement was used. Periodically, deep breathing was encouraged. All operations were performed with the patients supine.

TABLE 2. Pulmonary Function of Patients Anesthetized with Spinal or General Anesthesia 24 to 48 Hours Preoperatively*

	Spinal Anesthesia (mean ± SD)	General Anesthesia (mean ± SD)
Vital capacity	94 ± 9	95 ± 10
Residual volume (RV)	145 ± 20	163 ± 23
Total lung capacity (TLC)	101 ± 15	102 ± 18
RV/TLC	202 ± 17	188 ± 18
MVV	50 ± 17	51 ± 14
FEV_1	79 ± 32	72 ± 28
Pa_{O_2} (torr)	56.9 ± 3.2	55.3 ± 3.40
$Paco_2$ torr	50.3 ± 4.0	47.9 ± 2.20
pH_a	7.32 ± 0.02	7.34 ± 0.02

* Pulmonary function results reported as per cent of predicted value.

Blood Data. Blood samples were obtained anaerobically from all patients via a catheter inserted percutaneously into a brachial or radial artery. Samples were collected: 1) before induction of anesthesia; 2) approximately mid-way through the operative procedure; 3) at the conclusion of operation; 4) approximately an hour following surgery; 5) approximately four hours following surgery.

After the first recovery-room blood samples had been obtained, all subjects were encouraged to breathe deeply.[6] Meperidine (20–30 mg) was administered intravenously as necessary for pain relief during the first four hours postoperatively (maximum dose, 80 mg).

RESULTS

There were no significant differences between the physical characteristics and lengths of of operation times in the two groups of patients (table 1). RV and RV/TLC were larger than normal, the VC was reduced, and FEV_1 was

prolonged in every patient studied. The mean values in the two groups were comparable ($P > 0.1$) (table 2).

pH_a and $Paco_2$ did not change significantly during or after operation in either group ($P > 0.1$) (table 3). Pa_{O_2} values increased in both groups when F_{IO_2} was raised to 0.40, but returned to preoperative levels at the one- and four-hour postoperative periods (table 3).

Discussion

Using blood gas values as the tool for comparison, our data reveal no difference between values with spinal anesthesia and pentothal–halothane–nitrous oxide–oxygen anesthesia. Elderly men with obstructive pulmonary disease easily tolerated lower abdominal operations with either technique.

The problems associated with general anesthesia in the emphysematous patient have been reviewed by Nunn.[7] High spinal anesthesia, on the other hand, may interfere with the mechanics of respiration by producing an inefficient diaphragmatic shape and an increased breathing work-load on intercostal muscles.[8] Decreased elasticity of the lungs and resistance to expiratory air flow, common with emphysema, may necessitate active exhalation. Since the principal muscles of exhalation are abdominal, spinal anesthesia might affect respiration in such patients adversely.

In patients with emphysema and CO_2 retention, hypoxemia may act as a respiratory defense mechanism via the chemoreceptors of the carotid body and aortic arch. Thus, when these patients breathe an oxygen-enriched atmosphere, the resultant increases in Pa_{O_2} may reduce or abolish the respiratory drive.[10] However, our patients did not have decreases in ventilation despite increased Pa_{O_2}'s. In fact, those patients with chronic hypercarbia had lower $Paco_2$ values immediately after operation than preoperatively, despite elevated F_{IO_2} and Pa_{O_2} values. This phenomenon is being examined further.

The study of Paskin *et al.*[1] indicated that spinal anesthesia in the emphysematous patient caused only slight impairment of forced expiratory muscle function, with only a moderate increase in physiologic deadspace. Alveolar ventilation and respiratory gas exchange were not impaired. Similar results have been found in normal subjects.[5,9]

The close agreement of blood gas values obtained 24 to 48 hours preoperatively in this study with values obtained immediately preoperatively indicates that the secobarbital–atropine premedication (in this dose range) neither depressed $\dot{V}_A$ nor changed $\dot{V}_A/\dot{Q}$. Although Stein[12] believed that there was a prohibitive incidence of postoperative pulmonary complications associated with patients with Pco_2 values greater than 50 torr, there was no evidence of deterioration of respiratory function, as determined by blood gas analysis or clinical evaluation, in any of our 20 patients examined daily for four days.

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Table 3. Arterial Blood Gas Values of Patients Anesthetized by Spinal and General Techniques*

	Preoperation F_{IO_2} = 0.21	Midoperation F_{IO_2} = 0.40	Endoperation F_{IO_2} = 0.40	Postoperation (1 hour) F_{IO_2} = 0.21	Postoperation (4 hours) F_{IO_2} = 0.21
Spinal anesthesia (n = 10)					
$Paco_2$ (torr)	49.7 ± 3.1	46.2 ± 3.8	44.8 ± 4.6	45.9 ± 4.4	47.4 ± 3.4
pH_a	7.33 ± 0.02	7.36 ± 0.03	7.37 ± 0.04	7.36 ± 0.03	7.34 ± 0.02
Pa_{O_2} (torr)	57.8 ± 4.3	139.4 ± 24.2	141.8 ± 26.4	62.8 ± 5.7	58.4 ± 3.5
General anesthesia (n = 10)					
$Paco_2$ (torr)	48.3 ± 2.0	44.8 ± 5.2	44.4 ± 3.4	47.3 ± 3.4	48.3 ± 3.6
pH_a	7.34 ± 0.02	7.37 ± 0.02	7.37 ± 0.03	7.35 ± 5.8	7.34 ± .02
Pa_{O_2} (torr)	55.4 ± 5.3	143.6 ± 21.5	143.1 ± 20.6	56.1 ± 7.1	55.9 ± 5.1

* Results are reported as mean ± SD. No statistical difference between values for spinal and general techniques was found at any time period ($P > .1$).

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Hypoxemia during Cardiopulmonary Bypass

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The commercial disposable bubble oxygenator for open-heart surgery has found wide application since its introduction in 1957.[1]

In 1966, DeWall *et al.*[2] introduced the Temptrol † disposable blood oxygenator, which has been routinely used for all patients undergoing open-heart surgery during the past 18 months in this hospital. It has provided full oxygenation during cardiopulmonary bypass, elimination of carbon dioxide without destruction of blood elements, and the capacity for lowering or raising blood temperature in minimal time.

During January 1971, three patients undergoing open-heart surgery developed noticeable hypoxemia while on bypass. The most recent case is described below.

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REPORT OF A CASE

A 62-year-old man weighing 83 kg was scheduled for myocardial revascularization by saphenous vein bypass graft of the right posterior coronary artery. He had angina which had been steadily increasing in severity for 13 years.

Premedication consisted of morphine, 9 mg, and atropine, 0.5 mg. Induction of anesthesia with thiopental, 150 mg, and succinylcholine, 100 mg, to facilitate intubation was uneventful. Anesthesia was maintained with nitrous oxide and oxygen in a 50 per cent mixture. Morphine and *d*-tubocurarine were given in increments as needed. Electrocardiogram, central venous pressure, arterial pressure, blood gases, rectal and esophageal temperatures, serum electrolytes and urinary output were continually monitored.

Cannulation and the proximal vein-to-aorta anastomosis proceeded smoothly. The patient was then placed on cardiopulmonary bypass for the distal anastomosis. A Sarns console with the Temptrol disposable blood oxygenator was used. Venous return, after going onto total bypass, was good, and a flow rate of 60 ml/kg (4,980 ml/