reservoir extension an increase in inspiratory flow rate or tidal volume decreases \( F_{O_2} \) by air entrainment. Elevation of \( F_{O_2} \) is achieved by the addition of reservoir extensions and by increasing oxygen flow. As a corollary, hyperventilation then increases the inspired oxygen concentration.

This system has also proved useful in the evaluation and weaning of nonsurgical patients who have undergone long-term mechanical ventilation via tracheostomies.

REFERENCES

A New and Simple Method for Ventilating Patients Undergoing Bronchoscopy

J. Oulton, B.Sc., M.D.C.M., C.R.C.P.(C) ‡

Techniques for assisting or controlling the ventilation of patients under general anesthesia for bronchoscopic examinations have varied widely over the years. Muendrich,1 in 1953, introduced the ventilating bronchoscope, thereby utilizing various closed-system pressures for ventilation in the bronchoscope itself. Sanders,2 in 1967, reported his technique, in which a needle was attached at the bronchoscope opening, through which oxygen under pressure was forced intermittently. This jet evoked the venturi effect so that the oxygen plus the entrapped room air provided the necessary pressures and volumes for ventilation. Spoor,3 in 1969, added to the Sanders attachment a Bird Mark II ventilator, which provided automatic ventilation. This report
describes a method of ventilation which utilizes the bronchoscope sidearm only for attachment.

APPARATUS

The apparatus (fig. 1) consists of a length of high-pressure oxygen hose with a male bayonet connector, an adjustable one-stage reducing valve (IH519 de Vilbiss air regulator) with a 0-to-100-psi range, an ARO Corporation Blow Gun (model 7444), and a length of soft rubber tubing. The male bayonet connector, at one end of the high-pressure hose, is plugged into the hospital oxygen pipeline. The other end of the hose is attached to the inlet of the adjustable reducing valve. A further length of pressure hose connects the reducing valve outlet to the input of the blow gun. The output of the blow gun is then connected to the bronroscope sidearm via a soft rubber hose. Two steps are required for operation: adjustment of the reducing valve to a predetermined setting, and intermittent pressure on the blow gun button. The speed with which the button is depressed and the length of time it is held down will be judged by direct observation of the rise and fall of the chest.

EXPERIMENTAL STUDIES

Bronchoscopes of different sizes were tested to determine the reducing valve pressures necessary to deliver predetermined pressures at their distal ends (tapered, Chevalier Jackson sizes 3½–9 mm; straight, Chevalier Jackson sizes 8 and 6 mm, Holinger 4 and 5 mm). A manometrically calibrated Bourdon type of pressure gauge was attached to the distal end of the test bronchoscope, which had all the side vents sealed. With the blow gun button fully depressed, the reducing valve was adjusted to produce pressure gauge readings of 15, 30, and 45 cm H₂O, respectively (table 1).

The design of bronchoscopes is such that the simultaneous occlusion of all the side vents is virtually impossible. It is highly unlikely, therefore, that the maximum pressures, as shown in table 1, would be attained. The following experiment was carried out to determine the effect of the pressure in the bronchoscope with the side vents open: the redu-

Table 1. Pressures of Gas Leaving the Reducing Valve Needed to Deliver 15, 30, and 45 cm H₂O Maximum Pressures at the Ends of Various Bronchoscopes

<table>
<thead>
<tr>
<th>Internal Diameter (mm)</th>
<th>Pressures of Gas (psi) Needed at End of Bronchoscope a Pressure of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 cm H₂O</td>
</tr>
<tr>
<td>Straight bronchoscopes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Tapered bronchoscope</td>
<td></td>
</tr>
<tr>
<td>3½</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>12½</td>
</tr>
<tr>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>17½</td>
</tr>
<tr>
<td>9</td>
<td>14</td>
</tr>
</tbody>
</table>
Fig. 2. The pressures developed at the tips of three bronchoscopes as the side vents are opened. They were first set to deliver 45 cm H₂O pressure with all the side vents occluded.

A clinical trial using as subjects six patients undergoing bronchoscopy was carried out (table 2). The patients were premedicated with Demerol and atropine. The reducing valve was adjusted to give 45 cm H₂O maximum pressure in the bronchoscope (see table 1). A sleep dose of thiopental, 2.5 per cent, was administered intravenously, followed by 60 to 80 mg succinylcholine. Ventilation with 100 per cent oxygen by mask was administered for 30 seconds, the bronchoscope was introduced by the surgeon, and the ventilator then connected to the sidearm. Ventilation was continued by this means alone until the bronchoscope was withdrawn. Additional thiopental and succinylcholine were given as required.

Arterial blood samples obtained by radial or brachial artery puncture were drawn into a heparinized syringe prior to induction of anesthesia and just before withdrawal of the bronchoscope. Oxygen tensions and pH readings were obtained from an Astrup Radiometer P.H.M. 27, and a Severinghaus direct-reading

![Diagram](image-url)
electrode was used for CO₂ tensions. Bicarbonate levels were calculated from the Siggaard-Andersen alignment nomogram.

Assisted ventilation was administered by an anesthetist in each case. There were small variations in the extent and length of time the blow gun button needed to be depressed. A rate of approximately 15 cycles/min was used.

**DISCUSSION**

The results (table 1) show that the bronchoscopes tested with our system are capable of

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**Table 2. Arterial Blood Gas Readings for Six Patients Undergoing Bronchoscopy**

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
<th>Patient 5</th>
<th>Patient 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set</strong></td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>72</td>
<td>67</td>
<td>61</td>
<td>61</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td><strong>Bronchoscope size</strong></td>
<td>X 10</td>
<td>X 10</td>
<td>X 10</td>
<td>X 10</td>
<td>X 10</td>
<td>X 10</td>
</tr>
<tr>
<td><strong>Length of procedure (min)</strong></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

**Before bronchoscopy**

- **Pao₂ (mm Hg)**
  - Patient 1: 69
  - Patient 2: 65
  - Patient 3: 45
  - Patient 4: 67
  - Patient 5: 91
  - Patient 6: 64

- **Paco₂ (mm Hg)**
  - Patient 1: 35
  - Patient 2: 41
  - Patient 3: 68
  - Patient 4: 46
  - Patient 5: 43
  - Patient 6: 30

- **pH**
  - Patient 1: 7.35
  - Patient 2: 7.26
  - Patient 3: 7.36
  - Patient 4: 7.37
  - Patient 5: 7.38
  - Patient 6: 7.41

- **Bicarbonate (mEq/L)**
  - Patient 1: 22.1
  - Patient 2: 24
  - Patient 3: 35.5
  - Patient 4: 26.5
  - Patient 5: 25
  - Patient 6: 31.5

**During bronchoscopy**

- **Pao₂ (mm Hg)**
  - Patient 1: 480
  - Patient 2: 365
  - Patient 3: 270
  - Patient 4: 435
  - Patient 5: 440
  - Patient 6: 360

- **Paco₂ (mm Hg)**
  - Patient 1: 33
  - Patient 2: 32
  - Patient 3: 63
  - Patient 4: 40
  - Patient 5: 42
  - Patient 6: 32

- **pH**
  - Patient 1: 7.44
  - Patient 2: 7.44
  - Patient 3: 7.39
  - Patient 4: 7.41
  - Patient 5: 7.46
  - Patient 6: 7.42

- **Bicarbonate (mEq/L)**
  - Patient 1: 22.5
  - Patient 2: 22
  - Patient 3: 35.5
  - Patient 4: 25.2
  - Patient 5: 20
  - Patient 6: 31.5
delivering a maximum pressure of 45 cm H₂O utilizing the pressure of hospital pipeline oxygen (55 to 60 psi). It is not necessary to have an oxygen cylinder as a pressure source.

An airway pressure of 45 cm H₂O is high and would rarely be used clinically. However, the results in figure 2 show that it is very unlikely that this pressure would be obtained in the lungs themselves. To obtain such a pressure, not only would all the side vents need to be sealed and the bronchoscope tip need to be a tight fit, but also the blow gun-inflating button would have to be fully depressed until the chest would expand no more.

Flow rates were adequate, as seen from the results in figure 4, and oxygen concentrations delivered were never less than 98 per cent. Flow control is progressive, however, and depends on the extent of depression of the button. Therefore, the button is depressed just enough to give the desired flow rate as judged by observation of chest expansion.

The clinical trials (table 2) showed that when the ventilator is set to deliver 45 cm H₂O maximum pressure, adequate ventilation, as shown by the CO₂ levels, is easily obtainable. Oxygen levels in all cases were above 250 mm Hg.

There were no complaints from the bronchoscopists during this trial period. In fact, the operators were impressed by both the clear field of vision and the freedom from misting of the telescope lenses due to the dry gas flow.

REFERENCES


A Method of Fixation of Nasotracheal Tubes in Infants

RALPH A. EPSTEIN, M.D.*

Proper fixation of the nasotracheal tube is necessary for safe long-term mechanical ventilation of the infant or small child. There should be maximum mobility of the child with minimum risk of displacement of the airway. Additionally, the fixation apparatus should be readily available, simple, and lightweight, and should facilitate suctioning. A special nasotracheal tube described for this purpose has a crosspiece built into its proximal end. Unfortunately the design of this special tube has introduced other difficulties. The length of the tube can be adjusted only by cutting the distal end. This is impossible after intubation. Additionally, we have often found it difficult to pass suction catheters through the crosspieces of very small tubes. For this reason we

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FIG. 1. Diagram of the apparatus. A and B, ventilator tubing; C, "tracheostomy adapter"; D, plastic elbow; E, 3/8" i.d. silicone rubber tubing; F, aluminum crosspiece with suction port; G, "tracheostomy adapter"; H, nasotracheal tube.