Treatment for Collapsed Lung in Critically Ill Patients*

Selective Intrabronchial Air Insufflation Using the Fiberoptic Bronchoscope

Thomas Chang-Yao Tsao, M.D.; Ying-Huang Tsai, M.D., F.C.C.P.;
Ray-Shee Lan, M.D., F.C.C.P.; Wen-Bin Shieh, M.D., F.C.C.P.; and
Cheng-Huei Lee, M.D., F.C.C.P.

A new, simpler method to re-expand collapsed lungs was introduced in 14 procedures in 12 critically ill patients. To close the bronchus, we wedge the fiberoptic bronchoscope into each segment or subsegment of the collapsed lung instead of using a balloon cuff. Room air was then insufflated into the atelectatic alveoli after repetitive sputum suctioning and bronchial washing with normal saline solution. Complete re-expansion was achieved in 12 of the 14 procedures and partial in two. The average alveolar-arterial oxygen pressure difference (P[A-a]O2) declined from 217.5 before the procedure to 200.3, 150.0 and 152.2, respectively at 30 minutes, 12 hours and 24 hours after. There were no complications. (Chest 1990; 97:435-38)

Collapsed lung is a common problem in critically ill patients. Although respiratory therapy is a primary and effective method of treatment, it is not suitable for some patients, such as those with rib fractures, hemothorax, or pneumothorax. Other patients are too critical to wait for the results of repetitive respiratory care or cannot tolerate vigorous therapy. In 1973, a bedside procedure was introduced to re-expand the collapsed lung using a fiberoptic bronchoscope.1 This procedure includes repetitive sputum suctioning and bronchial washing with normal saline solution. Although most of the lung collapse was re-expanded with the above procedure, some were refractory. This may be due to a lower lung compliance and higher critical opening pressure in the collapsed lung. If the collapse is left untreated it may become chronic and a secondary infection may occur. Many devices were invented to overcome the lower lung compliance and higher critical opening pressure. Intrabronchial positive pressure ventilation using an endotracheal tube or a bronchoscope with a balloon cuff was introduced. All attained good results.2-5 Unfortunately, these devices are complex and not readily available. We designed a simpler method to accom-

Table 1—Clinical Data and Chest X-Ray Film Findings on Patients Undergoing Fiberoptic Bronchoscopic Procedures

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>Underlying Condition</th>
<th>Collapse Area</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>M</td>
<td>R't rib fracture with hemothorax, septic shock, acute renal failure</td>
<td>RLL</td>
<td>CR*</td>
</tr>
<tr>
<td>2</td>
<td>52</td>
<td>M</td>
<td>Traumatic hemoptoeumothorax</td>
<td>L't lung</td>
<td>CR</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>M*</td>
<td>R't rib fracture with hemoptoeumothorax</td>
<td>RLL</td>
<td>CR</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
<td>F</td>
<td>Esophageal stricture for corrosive injury s/p colon interposition</td>
<td>L't lung</td>
<td>CR</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>F*</td>
<td>L't renal cell cancer with radical nephrectomy</td>
<td>RUL</td>
<td>PR</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>M</td>
<td>R't lower limb large skin defect with infection, septic shock</td>
<td>L't lung</td>
<td>CR</td>
</tr>
<tr>
<td>7</td>
<td>48</td>
<td>F</td>
<td>Diabetic mellitus with uraemia post CPR, hypoxic encephalopathy</td>
<td>L't lung</td>
<td>CR</td>
</tr>
<tr>
<td>8</td>
<td>29</td>
<td>M</td>
<td>NPC post R/T, radiation myelopathy above C2 level with quadriplegia</td>
<td>LLL</td>
<td>CR</td>
</tr>
<tr>
<td>9</td>
<td>28</td>
<td>F*</td>
<td>SLE with pulmonary infection and respiratory failure</td>
<td>LLL</td>
<td>CR</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>M</td>
<td>BAT with internal bleeding post splenectomy</td>
<td>L't lung</td>
<td>CR</td>
</tr>
<tr>
<td>11</td>
<td>52</td>
<td>F</td>
<td>RHD post AVR + MVR + tricuspid annuloplasty</td>
<td>RLL</td>
<td>CR</td>
</tr>
<tr>
<td>12a</td>
<td>16</td>
<td>M</td>
<td>Traumatic CS, C6 dislocation with quadriplegia</td>
<td>LUL + RUL</td>
<td>CR</td>
</tr>
<tr>
<td>12b</td>
<td></td>
<td></td>
<td></td>
<td>LUL + RUL</td>
<td>PR</td>
</tr>
<tr>
<td>12c</td>
<td></td>
<td></td>
<td></td>
<td>RUL</td>
<td>CR</td>
</tr>
</tbody>
</table>

* Chest x-ray film with air bronchogram.
†CR, PR: complete and partial re-expansion.
Arterial blood gas values were checked just before the bronchoscopic procedure, then 30 minutes, 12 and 24 hours after. A portable chest x-ray examination followed soon after the procedure.

RESULTS

After 12 of the 14 procedures, the chest x-ray film showed complete reexpansion; in the remaining two, case 5 and the secondary procedure in case 12, the x-ray film showed partial re-expansion. In case 5 the collapsed lung reexpanded completely after six days of continuous, intensive, pulmonary care. In case 12, a third bronchoscopic procedure was performed with immediate full re-expansion (Table 1).

Case 1 and case 6 died of septic shock 24 and 26 hours after the bronchoscopic procedure. Their arterial blood gas value worsened, and they were excluded from the analysis of PaO$_2$ and P(A-a)O$_2$ because the worsening was thought to be due to underlying sepsis. A blood gas value was not obtained after case 12's third procedure. After excluding the above three procedures, the PaO$_2$ of the remaining 11 procedures improved from 79.0 before the procedure to 86.5, 112.1 and 90.6 mm Hg, respectively at 30 minutes, 12, and 24 hours after. The P(A-a)O$_2$ declined from 217.5 to 200.3, 150.0 and 152.2 (Fig 2).

In case 12, the RUL collapse recurred two days

**FIGURE 1.** The whole apparatus included a fiberoptic bronchoscope, an Ambu bag and a pressure gauge were connected to a three-way adaptor (arrow).

**MATERIALS AND METHODS**

Twelve patients were admitted to the medical or surgical ICU for the different critical conditions (Table 1). The duration of lung collapse ranged from 24 to 120 hours. All had received intensive respiratory care since admission to prevent atelectasis. When the lung collapsed, another 24 hours of respiratory therapy was performed before the fiberoptic bronchoscopic procedure.

A fiberoptic bronchoscope was used. A three-way adaptor was connected to the suction channel of the bronchoscope. One port was used to introduce room air by Ambu bag, the other port was connected to a pressure gauge to monitor the peripheral airway pressure during air insufflation (Fig 1).

The bronchoscopy was performed transnasally in the four patients who were not intubated. In the eight intubated patients, the bronchoscopy was performed through a swivel adaptor connected to the mechanical ventilator as described in previous studies. Repetitive sputum suctioning and bronchial washing with normal saline solution was done until all the visualized airways were clear. We then wedged the bronchoscope into each segment or subsegment of the collapsed lobe and rapidly insufflated room air into the selected airways by Ambu bag for one to two minutes, keeping the peripheral airway pressure around 30 cmH$_2$O or 10 cmH$_2$O higher than the previous airway pressure. The duration of the 14 procedures ranged from 20 to 30 minutes. The eight intubated patients received 100 percent oxygen by mechanical ventilation during the whole procedure. The four nonintubated patients were given as high as possible FIO$_2$ by mask. The vital signs were monitored by ECG monitor and arterial line or frequent measurement by sphygomanometer.

**FIGURE 2.** The average alveolar-arterial oxygen pressure difference (P(A-a)O$_2$) improvement during 24 hours following fiberoptic bronchoscopic procedure.
after the first bronchoscopic procedure. He underwent two further procedures with subsequent reexpansion. In case 8, the LLL collapse recurred six days later. A repeat bronchoscopic procedure was recommended but was refused by the patient. This lesion remained at discharge four weeks later.

Discussion

Collapsed lung is one of the important problems in critically ill patients, and the clinical condition may worsen rapidly. Treatment with a therapeutic fiberoptic bronchoscopic procedure at the bedside was introduced and good results were reported in many studies. When this therapeutic procedure includes repetitive sputum suctioning and bronchial washing with normal saline solution; complete or partial re-expansion of atelectasis was attained in 60 to 90 percent of the cases.\(^6\)

When the lung volume decreases, the alveolar radius will decrease and the alveolar pressure rise according to Laplace relationship: \(P_r = 2 \frac{T}{r}\) (\(P_r\)-alveolar pressure, \(T\)-alveolar surface tension, \(r\)-alveolar radius). In these conditions, the surfactant will work to lower the alveolar surface tension; this reduction in surface tension offsets the reduction in alveolar radius and prevents alveolar pressure from rising. But if the atelectasis is profound, the reduction in surface tension can not overcome the reduction in alveolar radius, and the alveolar pressure will rise and create a higher critical opening pressure in the atelectatic alveoli and lower lung compliance. The above findings are especially common in cases with a small area of collapse. In these cases, the transpulmonary pressure of the atelectatic alveoli is often low to overcome the critical pressure.\(^11\) These refractory atelectasis do not easily re-expand even after the above bronchoscopic procedures. It would be useful if we could introduce positive pressure ventilation directly into the collapsed area to overcome the critical opening pressure. But if we can not inflate the air directly into the atelectatic alveoli, the insufflated air will tend to be distributed into the noncollapsed areas because of lower airway resistance and higher lung compliance. This will result in a hyperinflated normal lung area which in turn will compress the collapsed area.

In order to introduce air selectively into the atelectatic alveoli only, a few methods and devices were designed using a rigid or fiberoptic bronchoscope with a balloon cuff. After the bronchoscope was introduced into the collapsed lobar bronchus, the cuff was inflated to close the bronchus during air insufflation.\(^3\) Although these special devices obtained good results, they are still complex and not readily available. Therefore, we simply wedged the bronchoscope into each segment or subsegment of the collapsed lobe to close the bronchus.

Harada et al\(^4\) stated that the atelectatic lung barely reexpanded following positive pressure ventilation through the endotracheal tube under about 20 cm \(H_2O\) airway pressure when observed during fiberoptic roentgenograms or surgery. Mutsuda et al\(^6\) exerted positive pressure in the lung of adult dogs through the trachea after tracheostomy and found no damage to the lungs at pressures under 30 cm \(H_2O\); however, rupture and bleeding of alveoli were observed under 60 cm \(H_2O\). So, in this study the peripheral airway pressure was monitored by a pressure gauge connected to the bronchoscope and it was kept around 30 cm \(H_2O\), or 10 cm \(H_2O\) higher than the previous airway pressure during air insufflation. This pressure was high enough to overcome the critical opening pressure, but did not result in complications such as pneumothorax or pulmonary hemorrhage.

In seven of our 14 procedures, the duration of collapse had been more than 48 hours. In nine, the atelectatic areas were limited to one lobe. In three, the chest x-ray film showed air bronchograms in the collapsed lung. All of the above conditions were documented to be handicaps to reexpansion of atelectasis in previous studies.\(^11\) The collapsed lung reexpanded completely soon after 12 of the bronchoscopic procedures, and partially in two. Arterial blood gas values following the procedure showed apparent improvement of \(PaO_2\) and \(P(A-a)O_2\) in all. No significant complications resulted from these 14 bronchoscopic procedures, although transient tachycardia or hypertension developed in some cases.

Marini et al\(^14\) described that intensive respiratory care had the same effect on acute lobar collapse when compared with bronchoscopic procedures, but half of our cases suffered from chest trauma or spinal cord injury. These cases were excluded from his study for intolerance of respiratory care. Moreover, all of our cases were in critical condition and might not survive if we could not correct the pulmonary impairment immediately.

In conclusion, we suggest a new simpler, effective method to introduce selective intrabronchial positive ventilation. We just wedge the bronchoscope into each segment or subsegment of the collapsed lobe instead of using the balloon cuff to close the bronchus. There were no complications even in critical cases.

References

2. Sachdeva SP. Treatment of post-operative pulmonary atelectasis by active inflation of the atelectatic lobes (s) through an endobronchial tube. Acta Anesth Scand 1974; 18:65-70

CHEST / 97 / 2 / FEBRUARY, 1990

437

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