Positive End-Expiratory Pressure in the Management of Lobar Atelectasis*

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Positive end-expiratory pressure (PEEP) has been extensively utilized in the treatment of severe hypoxemia from noncardiogenic pulmonary edema. The usefulness of therapy with PEEP in the management of lobar atelectasis has not been previously stressed. Recently, we observed four patients with lobar atelectasis who failed to respond to the usual conservative measures of endotracheal suctioning and thoracic physiotherapy. Atelectasis was confirmed by physical examination and chest x-ray films, and three of the four patients subsequently underwent fiberoptic bronchoscopic examination. Endobronchial obstruction was not found, and despite extensive irrigation and suctioning, the atelectasis failed to resolve. Therapy with PEEP was then added, with pressures of 5 to 15 cm H₂O. Serial chest x-ray films disclosed resolution of the atelectasis within 4½ hours in two patients, within 14 hours in one patient, and within 24 hours in the remaining patient.

Therapy with positive end-expiratory pressure (PEEP) is frequently used in the management of severe hypoxemia from noncardiogenic pulmonary edema. The application of PEEP in the treatment of atelectasis which persists after bronchial obstruction has been corrected or excluded may also be associated with dramatic clinical and physiologic improvement. Segmental or lobar atelectasis is a frequent complication in the patient undergoing abdominal or thoracic surgery; and for years, this disorder has been the subject of numerous publications purporting methods to effectively prevent or manage the problem. In this report, four patients whose condition failed to respond to conservative measures to correct atelectasis were successfully treated with endotracheal intubation and PEEP.

Case Reports

Case 1

A 41-year-old white woman with known asthma was hospitalized for aortoliac endarterectomy. On the first day following surgery, the patient was noted to be tachypneic, and arterial blood gas levels disclosed mild hypoxemia (arterial oxygen pressure [PaO₂] of 66 mm Hg). The chest x-ray film demonstrated atelectasis of the right middle and right lower lobes (Fig 1). The patient was noted to have poor inspiratory effort due to abdominal pain. Thoracic physiotherapy and treatment with intermittent positive pressure breathing failed to reexpand the atelectatic lobes, and fiberoptic bronchoscopic examination was performed. Minimal secretions without obstruction were noted. Postbronchoscopic chest x-ray films demonstrated persistent atelectasis. The patient was intubated and ventilated with a volume ventilator (Puritan-Bennett MA-1). Therapy with a PEEP of 5 cm H₂O was begun. Four and one-half hours later, resolution of the atelectasis was noted (Fig 2). The PaO₂ following reexpansion was 131 mm Hg with a fractional concentration of oxygen in the inspired gas (FIO₂) of 0.30.

Case 2

A 34-year-old black man was admitted to the renal transplant unit because of altered mental status occurring three months after renal transplantation. While in the hospital, the patient experienced a generalized seizure, with vomiting and aspiration of gastric contents. Because of continued seizure activity, the patient was intubated for ventilatory control. Four days following intubation, atelectasis of the right upper

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Figure 1. Atelectasis of right middle and right lower lobes (case 1).
lobe was noted. The PaO\textsubscript{2} was 70 mm Hg with an FI\textsubscript{O}{2} of 0.40. Examination with a rigid bronchoscope was performed and was followed by partial reexpansion of the right upper lobe. Vigorous thoracic physiotherapy and bronchial drainage were continued, with the patient receiving mechanical ventilation. Serial chest x-ray films showed persistent atelectasis over a period of five days. Fiberoptic bronchoscopic examination was performed, with removal of thin secretions from the bronchus of the right upper lobe. The atelectasis persisted; and on the following day, therapy with a PEEP of 10 cm H\textsubscript{2}O was administered. Reexpansion of the atelectatic lobe was noted within 14 hours. The PaO\textsubscript{2} was 165 mm Hg with an FI\textsubscript{O}{2} of 0.40 following correction of the atelectasis.

CASE 3

A 23-year-old white woman who was the victim of an automobile accident required exploratory laparotomy and splenectomy. After surgery a 30 percent right-sided pneumothorax was noted. Twenty-four hours following insertion of a chest tube, atelectasis of the right upper lobe was noted. Therapy with mechanical ventilation via a volume ventilator was instituted. The PaO\textsubscript{2} was 60 mm Hg with an FI\textsubscript{O}{2} of 0.45. Considerable splinting of the right hemithorax was noted. Thoracic physiotherapy was instituted but was poorly tolerated by the patient because of pain. Fiberoptic bronchoscopic examination showed no bronchial obstruction, but chest x-ray films demonstrated persistent atelectasis following the procedure. Therapy with PEEP was administered at pressures ranging from 5 to 10 cm H\textsubscript{2}O, without immediate reexpansion of the lobe. The PEEP was subsequently increased to 15 cm H\textsubscript{2}O, with reexpansion of the lobe observed within 24 hours. The PaO\textsubscript{2} following reexpansion was 90 mm Hg with an FI\textsubscript{O}{2} of 0.45.

CASE 4

A 15-year-old black boy was struck by an automobile and sustained closed trauma of the head, thoracic contusions, and a 15 percent right-sided pneumothorax. A chest tube was inserted. Following endotracheal intubation the patient received therapy with a volume ventilator. Twelve hours following admission, the chest x-ray film revealed atelectasis of the right upper lobe (Fig 3). The PaO\textsubscript{2} at this time was 62 mm Hg with an FI\textsubscript{O}{2} of 0.40. Serial chest x-ray films following intubation showed continued atelectasis. Therapy with a PEEP of 5 cm H\textsubscript{2}O was administered, and reexpansion of the atelectatic lobe was observed within four hours (Fig 4). The PaO\textsubscript{2} following reexpansion was 109 mm Hg (FI\textsubscript{O}{2} of 0.40). Therapy with mechanical ventilation was continued for 48 hours. The patient then extubated himself and did well.
Table 1—Data from Four Patients with Refractory Atelectasis Treated with PEEP

<table>
<thead>
<tr>
<th>Patient</th>
<th>Atelectasis</th>
<th>Pathologic Process</th>
<th>PEEP Required, cm H₂O</th>
<th>Time to Reexpansion, hr</th>
<th>PaO₂, mm Hg With Atelectasis</th>
<th>PaO₂, mm Hg After Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, F, 41</td>
<td>Right middle and lower</td>
<td>After abdominal surgery</td>
<td>5</td>
<td>4½</td>
<td>66</td>
<td>131</td>
</tr>
<tr>
<td>2, M, 34</td>
<td>Right upper</td>
<td>Aspiration</td>
<td>10</td>
<td>14</td>
<td>70</td>
<td>165</td>
</tr>
<tr>
<td>3, F, 23</td>
<td>Right upper</td>
<td>Pulmonary contusion</td>
<td>15</td>
<td>24</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>4, M, 15</td>
<td>Right upper</td>
<td>Pulmonary contusion</td>
<td>5</td>
<td>4</td>
<td>62</td>
<td>109</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Lobar or segmental atelectasis continues to be a major problem in clinical medicine.1-3 Regardless of the etiology of the atelectasis, whether postobstructive or nonobstructive, serious complications result from persistent collapse. The hypoxemia that occurs with atelectasis results from pulmonary arteriovenous shunting. Infection occurs because of relative stasis of secretions, with the growth of organisms that are normally carried mouthward by ciliary action. Atelectasis is commonly seen in patients who have undergone major abdominal or thoracic surgery.1,2 Because of pain, the patient does not cough effectively and demonstrates a poor inspiratory effort. Pulmonary atelectasis is also frequently associated with contusion of the chest, as well as chronic pulmonary disease when there are complicating pulmonary or extrapulmonary factors.

The therapy for atelectasis has utilized conventional techniques such as humidification, tracheal suction, thoracic physiotherapy, and bronchial drainage.4,5 Incentive spirometry has been advocated as a therapeutic mode to increase inspiratory volumes.4 Therapy with IPPB has been widely used to improve ventilation and to prevent or treat atelectasis.4

Recently, more specific techniques have been developed to attempt to reexpand the atelectatic lung. These include the use of cuffed endobronchial tubes and the ventilating bronchoscope, with inflation by a resuscitator bag.6,7 A system designed by Anderson et al8 utilizes a hand-held face mask to provide positive pressure at the end of exhalation. Application of positive airway pressure, whether in the form of constant positive airway pressure or PEEP, has been used to increase the functional residual capacity, decrease right-to-left shunting, and improve oxygenation.

The techniques presented in this report are the same as those used to manage hypoxemia in the adult respiratory distress syndrome.9-11 Therapy with PEEP at varying levels was provided by a standard volume ventilator, with a cuffed endotracheal tube completing the closed system. Endobronchial obstruction was excluded by fiberoptic or rigid bronchoscopic examination, and chest x-ray films after bronchoscopic examination verified the presence of persistent atelectasis. Table 1 summarizes the pertinent data relative to the management of four patients with refractory atelectasis.

It might be argued that the resolution of atelectasis that was demonstrated in these four patients could have occurred spontaneously or as a result of the effects of previously instituted therapy. The prompt resolution of roentgenologic evidence of atelectasis and the rapid improvement in the transfer of gases across the lung upon institution of therapy with PEEP suggested cause and effect.

Although PEEP is widely employed in the treatment of hypoxemia, it has not been commonly utilized to treat nonobstructive atelectasis. In this report, all patients either had undergone surgery or were suffering from pulmonary contusions or aspiration. The application of therapy with PEEP should be beneficial in treating atelectasis from other causes, and in refractory atelectasis the use of PEEP for reexpansion of the lung may be particularly appropriate. Once endobronchial obstruction has been ruled out, an approach that facilitates rapid reexpansion of the lung can prevent the complications of persistent atelectasis.

**REFERENCES**

6 Sachdeva SP: Treatment of postoperative pulmonary ate-
The Fleischner Society announces the establishment of the George Simon Memorial Fellowship Award. The purpose of this annual award is to honor Dr. Simon by perpetuating his interest in encouraging young physicians and investigators to carry out original work related to diagnostic imaging in the respiratory system.

The Fellowship will be awarded to that individual who submits the best original work relating to radiologic or other imaging in the respiratory system. The award will consist of a trip to the Fleischner Society Meeting and Course with all expenses paid, plus a cash prize. The 1979 meeting and course will be in Stockholm, Sweden, June 6 through June 13. The Fellowship Award winner will present his paper at the Fleischner Society Meeting. The time allotted for the presentation will be between 20-30 minutes.

Although the paper presented for the Fellowship Award can be the result of work done by several investigators, the senior author should be the applicant and the majority of the work should be his. Applicants should not be older than 40 years.

Submissions for the 1979 Award must be in the form of a complete scientific paper and should be sent to Richard H. Greenspan, M.D., Chairman, Department of Diagnostic Radiology, Yale University School of Medicine, 333 Cedar Street, New Haven, Connecticut 06510, on or before January 1, 1979. Further information can be obtained from the same source.