The Use of Intermittent Positive Pressure Breathing Following Thoracic Operations

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Respiratory insufficiency of a transient nature occurs frequently during the immediate postoperative course in pulmonary and cardiac surgery. An elevated pCO₂ together with a lowered pH and in some cases a lower arterial oxygen saturation have been observed as evidence of inadequate pulmonary ventilation. Several factors may be responsible: pain, muscular stiffness and spasm in the area of the incision result in a shallow respiration. Inadequate removal of bronchial secretion can lead to multiple smaller or larger areas of alveolar collapse. The amount of functioning lung tissue removed as well as swelling of lung tissue due to the trauma of handling have to be taken into consideration. Important, but almost inaccessible to measurements, is the patient's ability to perform extra work of ventilation; fatigue and exhaustion of the respiratory apparatus may rapidly lead to insufficiency. Respiratory depression caused by anesthetics and sedatives contributes considerably towards an inadequate respiratory exchange.

In most patients, the respiratory reserve is adequate to overcome these difficulties and they regain an adequate respiration alone or with the help of bronchial aspiration, breathing exercises, and judicious use of analgesic drugs or nerve blocks. In some cases the respiratory insufficiency may be a major factor in the development of complications such as atelectasis or pulmonary infection. In a small number of patients a low pulmonary reserve due to anatomic or physiologic factors will make compensation impossible and progression into respiratory failure inevitable.

As an example of this last group, the following case history is presented:

A 64-year-old patient with severe kyphoscoliosis required surgery for vascular insufficiency of his right leg. In spite of great care during induction of anesthesia, a precipitous fall in blood pressure occurred leading to cardiac arrest. The diagnosis was made instantaneously, his chest opened and the heart beat restored by manual massage. After closure of the incision it was decided that he should have a tracheotomy and that in view of his low respiratory reserve artificial respiration might be necessary. Therefore, a James tube (cuffed tracheotomy tube) was inserted. He regained consciousness rapidly, indicating that brain damage was avoided. His respiratory exchange was measured at frequent intervals and he only was able to maintain an exchange just below his requirements according to the Radford nomogram. A drop in the respiratory minute volume was noticed after several hours and respirator treatment was started using a Bird respirator (Fig. 1). He was on controlled respiration for ten days; thereafter, his chest incision was less painful and he was weaned off the machine during the following seven days by disconnecting the respirator for increasing time intervals. The patient is now well.

The indication for respirator treatment is in principle respiratory insufficiency; its recognition is discussed adequately by Björk, Baird and Bigelow, as well as by Fairley and Chambers. With the experience available it is now frequently possible to anticipate postoperative respiratory insufficiency in certain conditions.

The technique of tracheotomy as well as the management of these patients has been covered by Fairley and Chambers and we have adopted their regimen. If not ventilated immediately, the patient should be followed by a special routine for the observation of the respiratory efficiency. This would be indicated in the following conditions:

1. Chronic pulmonary congestion — "stiff lungs" pulmonary hypertension.
2. Lung resection in cases with borderline pulmonary function.
3. Operation upon an only remaining lung.

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4. Operation resulting in an unstable chest wall.\textsuperscript{11}
5. Cardiac surgery in cases with impaired pulmonary function.\textsuperscript{12}
6. Cardiac arrest associated with pulmonary surgery or borderline pulmonary function.

Though clinical observation is invaluable, it is not possible, except in cases of gross underventilation, to assess the respiratory function without measurements. Respiratory volumes can be estimated easily with a Wright respirometer, and underventilation may be confirmed by determination of pH, pCO\(_2\) and by oximetry, as demonstrated in Fig. 1.

Most patients with postoperative respiratory insufficiency accept intermittent positive pressure breathing readily and begin to relax their own respiratory efforts after the first few inflations. Signs of stress and underventilation such as poor color, perspiration, restlessness and anxiety (the complex picture of CO\(_2\) narcosis)\textsuperscript{9} tend to disappear within a short time. (The objective advantages are that the patient can be adequately ventilated and CO\(_2\) accumulation or hypoxia thus avoided.) Breathing after thoracotomy is a mental and physical effort and the factor of fatigue of the respiratory apparatus in cases with borderline respiratory reserve is an important one. Respiratory effort and fatigue can be assessed only by frequent observation of the patient, and where these factors are present, respirator treatment is indicated to avoid respiratory acidosis and hypoxia. Passive inflation of the chest is less painful than active breathing, and yet sedation can be used more liberally since the alveolar ventilation is controlled by the respirator and respiratory depression cannot occur. To this is added the advantage of a tracheotomy and the maintenance of a clear airway avoiding the accumulation of secretions as a potential source for atelectasis and infection.

The duration of intermittent positive pressure breathing varies and is influenced by many factors — it should be used until the patient can maintain an adequate alveolar ventilation without dyspnea, fatigue or CO\(_2\) accumulation. A few hours of intermittent positive pressure breathing can abolish respiratory insufficiency and thus change the postoperative course radically; two to three weeks may be required to allow stabilization of the chest wall. It is necessary to maintain intermittent positive pressure breathing in cases with borderline respiratory function until the patient has recovered full use of his

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Respiratory rate (RR), tidal volume (TV) and estimated tidal volume according to the Radford nomogram (RTV) in a patient with severe kyphoscoliosis following cardiac arrest. Arterial pH and arterial oxygen saturation are indicated at the time the samples were taken.}
\end{figure}
respiratory apparatus; often a period of weaning is required and should not be hastened unduly.

The use of respirator treatment following thoracic surgery has been advocated by Björk and Engström in Sweden. Björk and his associates reported in an exhibit at the World Congress of Anesthesiology 1960—245 cases where controlled ventilation was used after thoracic surgery with only 72 deaths.

It is obvious that only a small group of patients require respiratory assistance; but this group has a high mortality and would often be considered unsuitable for intrathoracic procedures. In view of this, Björk stated that "nowadays no major thoracic surgery should be undertaken without the facilities for postoperative respirator treatment."

Our own experience consists of nine cases (Table 1.) Their presentation will outline the problem concerned.

The first three cases had in common unusually stiff lungs due to chronic congestion or pleural thickening. All three were unable to maintain an adequate tidal exchange in the immediate postoperative period. The next three patients had cardiac arrest associated with poor respiratory function or lung resection. All three did well, had no residual damage and no further cardiac problems postoperatively. One with collapse of two lobes and a large air leak was ventilated for two days after a second thoracotomy and made an excellent recovery; in another, the trachea was severed in the process of a radical pneumonectomy; with four days' respirator treatment the postoperative course was uneventful.

Two died: one due to an undiagnosed brain tumor three days after operation, the other one due to uncontrollable infection after 26 days of respirator treatment. In this case, pneumonitis had been present before the beginning of respiratory assistance about one week after operation. Infection is a great problem. We have lost another patient with a crushed chest due to uncontrollable pneumonitis. It is possible that the prolonged use of broad spectrum antibiotics may be responsible for the development of an intractable infection with resistant strains. It may be better not to use antibiotics prophylactically in these patients.

### Table 1—Respirator Treatment after Thoracic Surgery

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Surgery</th>
<th>Indication for Resp. treatment</th>
<th>Duration (Days)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. J.F.R.</td>
<td>33</td>
<td>Mitral valvotomy and pericardectomy</td>
<td>&quot;Stiff lungs,&quot; chronic pulm. congestion</td>
<td>10</td>
<td>a.w.</td>
</tr>
<tr>
<td>Mrs. M.McT.</td>
<td>63</td>
<td>Thoracotomy for rapidly increasing traumatic hemothorax</td>
<td>&quot;Stiff lungs,&quot; respir. insufficiency postop.</td>
<td>5½</td>
<td>a.w.</td>
</tr>
<tr>
<td>Mrs. J.P.</td>
<td>51</td>
<td>Rt. pneumonectomy and thoracoplasty, Old empyema and partial thoracoplasty</td>
<td>&quot;Stiff lungs&quot; Chest deformity</td>
<td>1</td>
<td>died</td>
</tr>
<tr>
<td>Mr. V.C.</td>
<td>38</td>
<td>Left pneumonectomy for extensive bronchiectasis</td>
<td>Cardiac arrest during and immediately after surgery</td>
<td>4</td>
<td>a.w.</td>
</tr>
<tr>
<td>Mrs. M.F.</td>
<td>41</td>
<td>Bronchial hemorrhage—bilateral thoracotomy resection rt. upper lobe</td>
<td>Cardiac arrest, postop. resp. insufficiency</td>
<td>6</td>
<td>a.w.</td>
</tr>
<tr>
<td>Mr. McG.</td>
<td>64</td>
<td>Cardiac arrest during induction of anesthesia. Thoracotomy and massage</td>
<td>Postop., respiratory insufficiency Severe kyphoscoliosis</td>
<td>17</td>
<td>a.w.</td>
</tr>
<tr>
<td>Mr. J.V.</td>
<td>51</td>
<td>Rt. middle and upper lobectomy for bronchiectasis. Chest re-opened for air leak (possible leak for bronchial stump)</td>
<td>Collapse rt. lower lobe paradoxic breathing</td>
<td>2</td>
<td>a.w.</td>
</tr>
<tr>
<td>Mr. T.P.</td>
<td>55</td>
<td>Thoracic aortic aneurysm. Removal of two ribs</td>
<td>Pneumonitis Unstable chest wall</td>
<td>26</td>
<td>died</td>
</tr>
<tr>
<td>Mr. R.S.</td>
<td>54</td>
<td>Left radical pneumonectomy injury to trachea and rt. main bronchus and repair</td>
<td>Surgery on airway leading to only remaining lung</td>
<td>4</td>
<td>a.w.</td>
</tr>
</tbody>
</table>

a.w.—Alive and Well
Respirator treatment should not be undertaken lightly. Constant active attention by the physician and excellent nursing care, with devoted nurses who are familiar with the type of work, is imperative to obtain good results. The type of respirator used is of secondary importance as long as nurses and attending physicians are familiar with it.

The results of postoperative respirator treatment are very impressive. The control or avoidance of respiratory acidosis and hypoxia appear to have a significant influence on postoperative morbidity and mortality and can help to reduce the risk of thoracic surgery.

**Summary**

In nine patients with respiratory insufficiency following thoracic surgery, postoperative intermittent positive pressure breathing has been used. Subjective and objective improvement was seen in all patients with this treatment. One died with intractable infection, and another due to a brain tumor.

A case of cardiac arrest in a patient with severe kyphoscoliosis is described outlining the management of postoperative intermittent positive pressure breathing. In certain conditions postoperative respiratory insufficiency can be anticipated and these represent an indication for the use of respirator treatment in order to reduce the risk of such surgery.

**Resumen**

Se usó presión positiva intermitente en 9 enfermos con insuficiencia respiratoria después de cirugía torácica. La mejora subjetiva y objetiva se observó en todos. Uno murió de infección incontrolable y otro debido a tumor cerebral.

Un caso de paro cardíaco en un enfermo con Xifoescoliosis se describe subrayando el tratamiento con presión intermitente positiva. En ciertos casos la insuficiencia respiratoria puede verse y en ellos existe la indicación del tratamiento con e inspirador para disminuir el riesgo.

**Zusammenfassung**

Bei 9 Patienten mit respiratorischer Insuffizienz im Anschluß an einen thorax-chirurgischen Eingriff war eine postoperative intermittierende positive Druckatmung zur Anwendung gelangt. Bei allen sah man eine subjektive und objektive Besserung unter dieser Therapie. Ein Patient starb an einer behandlungsrefraktären Infektion und ein anderer infolge eines Hirntumors.

Es wird ein Fall von Herzstillstand mit schwerer Kyphoskoliose beschrieben, und die Handhabung der postoperativen intermittierenden positiven Druckatmung des näheren ausgeführt. Unter gewissen Umständen kann die postoperative respiratorische Insuffizienz verhindert werden, und dies stellt dann eine Indikation für den Einsatz der Respirator-Behandlung dar, um das Risiko solcher Operationen zu verringern.

**References**