Asynchronous Breathing Movements in Patients with Chronic Obstructive Pulmonary Disease*

Kumar Ashutosh, M.D.; † Robert Gilbert, M.D.; ‡ J. H. Auchincloss, Jr., M.D.; † and David Peppi

An electromagnetic ventilation monitor was used to record the separate anterior-posterior movements of the chest and abdomen during the breathing cycle in 30 patients with chronic obstructive pulmonary disease (COPD) and in 10 normal subjects. In all normal subjects and 17 COPD patients, the chest and abdomen movements were synchronous and in phase with the flow of air as measured with a spirometer. In 13 COPD patients chest movement was synchronous with the flow of air, but the abdomen moved inward suddenly near or at end inspiration and then outward during a variable part of expiration. Compared to COPD patients with a normal breathing pattern, those with asynchronous breathing movements had poorer ventilatory mechanics and 10 of the 13 were dependent on assisted ventilation. Nine of the 13 patients with asynchronous breathing have died in a 10 month period, a significantly higher mortality than in those with normal breathing.

A form of discoordination of the respiratory muscles (Hoover’s sign) was described as far back as 1920. The sign consisted of a drawing in of the costal margins during inspiration and indicated advanced airway obstruction. Abnormal movements of the chest and abdomen during breathing have been described in patients with respiratory failure, and expansion of the chest during expiration has been considered to be a contraindication for “weaning” from assisted ventilation. Campbell and Agostoni have observed contractions of the abdominal muscles during inspiration at large lung volumes in some normal subjects. Similarly Bergofsky has described an “asynchronous” breathing pattern in normal subjects suggestive of a downward descent of the diaphragm during expiration.

We have noted a previously undescribed type of asynchronous breathing movements in a number of patients with chronic obstructive pulmonary disease (COPD). The present study was undertaken to define and evaluate this asynchrony and to correlate its presence with the clinical state and prognosis.

*From the Department of Medicine, State University of New York Upstate Medical Center, Syracuse, New York.
† Fellow in Pulmonary Disease.
‡ Professor of Medicine.

This study was supported by Training Grant No. HL-05954 from the National Heart and Lung Institute, Research Grant No. 12995 from the National Heart and Lung Institute, Grant No. PN-10569 from the Heart Association of Upstate New York, a grant “Development of Respiratory Distress” from the New York Heart Assembly, and a grant from the Parker B. Francis Foundation.

Manuscript received June 5; revision accepted October 11.

Reprint requests: Dr. Ashutosh, Upstate Medical Center, Syracuse, New York 13210

CHEST, 67: 5, MAY, 1975

ASYNCHRONOUS BREATHING MOVEMENTS IN COPD 553
Table 1—Age, Pulmonary Function, and Survival Data for 30 COPD Patients

<table>
<thead>
<tr>
<th>Normal Breathing Pattern</th>
<th>Asynchronous Breathing Pattern</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>55.8 (13.1)</td>
<td>62.1 (8.6)</td>
</tr>
<tr>
<td>FEV₁, ml</td>
<td>700 (343)</td>
<td>392 (177)</td>
</tr>
<tr>
<td>FVC, ml</td>
<td>1524 (697)</td>
<td>793 (339)</td>
</tr>
<tr>
<td>FEV₁/VC%</td>
<td>46.9 (13.7)</td>
<td>53 (22.9)</td>
</tr>
<tr>
<td>Po₂ mm Hg</td>
<td>41.6 (10.2)</td>
<td>43.2 (13.9)</td>
</tr>
<tr>
<td>PCO₂ mm Hg</td>
<td>51.6 (10.8)</td>
<td>56.7 (15.9)</td>
</tr>
<tr>
<td>Receiving assisted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ventilation</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Died</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Total number of patients</td>
<td>17</td>
<td>13</td>
</tr>
</tbody>
</table>

Numbers in brackets are the standard deviations. NS = not significant; FEV₁ = one second forced expiratory volume; FVC = forced vital capacity; VC = vital capacity; p values refer to comparisons between the two columns. Arterial blood gases drawn off assisted ventilation with the patient breathing room air.

RESULTS

Normal Breathing Pattern

In these cases the spirometer, chest, and abdomen signals all showed synchronized upward deflections during inspiration and downward deflections during expiration (Fig. 1). Seventeen patients and all normal subjects showed this pattern.

Asynchronous Breathing Pattern

In this pattern the chest and abdomen signals did not move in unison. In the most common pattern in this category the chest signal was synchronous with the flow of air as registered by the spirometer, but the abdomen signal moved abruptly downward near or at the end of inspiration (indicating an inward motion of the abdominal wall) and then moved upward (expansion) later in expiration and continued to move upward during a variable part of the expiration (Fig 2). Seven patients with COPD showed this pattern continuously. Two other patients showed a similar pattern but inconstantly. In one of these the pattern was present only during sleep, and in the other it was present during unhindered breathing but was abolished while the patient breathed through the mouthpiece of the spirometer. In one patient the chest was generally coordinated with the flow of air but the abdomen pattern was totally erratic. In three more patients the chest and spirometer signals were synchronous but the abdomen, although rising during all of inspiration, fell abruptly at the end of inspiration, rose moderately early in expiration and then fell slowly during the remainder of expiration. In contrast to the pattern shown in Figure 2, the upward motion of the abdomen in these patients during expiration was less pronounced than the upward movement during inspiration. This is considered to be a milder form of asynchronous breathing but definitely abnormal.

Clinical Status, Course and Prognosis

Normal breathing pattern (17 patients). This group consisted of ten ambulatory patients studied during regularly scheduled outpatient visits, and seven patients hospitalized for acute respiratory fail-

FIGURE 1. Normal breathing pattern. All signals were recorded simultaneously. In this and subsequent figures, upward deflection is inspiration for spirometer signal and outward movement for chest and abdomen.

FIGURE 2. Asynchronous breathing pattern.
ure. Four of the hospitalized patients were receiving assisted ventilation at the time of study, the other three were being managed with a controlled oxygen program.

Two patients in this group died. One expired the day following study, probably of digitalis intoxication. The second patient died of respiratory failure nine months following study. The remaining 15 patients are alive and ambulatory with an average follow up period of 6.3 months, range 3 to 10 months. All four patients in this group who required assisted ventilation, therefore, were eventually removed from the respirator successfully.

Asynchronous breathing pattern (13 patients). Ten of these patients required assisted ventilation at the time of study. Another two were hospitalized for respiratory failure but did not require assisted ventilation. One patient was studied as an outpatient. His respiratory pattern became normal when breathing through a mouthpiece but was abnormal during quiet unhindered breathing (this was the only patient in whom the breathing pattern was different with and without a mouthpiece). The number of patients with asynchronous breathing requiring assisted ventilation was significantly greater by the Chi-square test (p < .02) than the number of patients with normal breathing patterns requiring assisted ventilation.

Nine of these patients have died of respiratory failure. Seven died within four months of study and two patients died within ten months of study. The other four patients are alive but with severe respiratory distress. Table 1 summarizes some of the comparisons and statistical analyses between the two groups.

Two patients who could not initially be removed from a respirator and who showed asynchronous breathing were trained to coordinate these movements. For half hour periods they were instructed to push out the abdomen during inspiration and relax during expiration. During these sessions the patient was attached to the magnetometer and the chest and abdomen movements were displayed for him on an oscilloscope as an aid in the training. These sessions were conducted three to five times per week. One patient required two to three weeks of training, the other ten days. Subsequently both patients became independent of the respirator. One died two months later and the other is ambulatory and attending the outpatient clinic. He has not required assisted ventilation for a follow up period of five months. The breathing pattern after training became normal in the first patient and converted to the milder form of the abnormal pattern in the second.

Type of disease. According to the criteria of Burrows et al., a majority of these patients had features of both chronic bronchitis and emphysema regardless of their type of breathing pattern. Of ten patients in whom features of emphysema predominated, five had normal and five had abnormal patterns. Of five who had predominantly the bronchitic syndrome, three had normal and two had abnormal breathing patterns. On lateral chest radiograph, the diaphragm was concave upward in 73 percent of the patients with abnormal patterns and in 44 percent with normal patterns; the difference, however, is not statistically significant.

Prior to study, approximately half the patients in both groups had a clinical course characterized by exacerbations and remissions of respiratory failure. The other half were either stable or had shown progressive deterioration to study. The high mortality in the abnormal breathing pattern group following study precludes a comparison of the subsequent course of the two groups of survivors.

**DISCUSSION**

We have presented a group of patients with COPD who showed asynchronous breathing movements. The movement of the chest was synchronous with the flow of air as registered by a spirometer, but the abdomen showed two distinct asynchronous movements with each breathing cycle. One was a rapid inward motion near or at the end of inspiration which quickly ended and was followed by an outward movement that continued for a variable period during expiration while the chest was still moving inward. These double abdominal movements were clinically detectable, although it was not possible to define exactly the different components by clinical observation alone.

Konno and Mead\(^\text{11}\) devised principles for quantitating the relative contributions of the rib cage and diaphragm to the tidal volume. We have used these principles in previous reports from our laboratory,\(^\text{9}\) but not in the present study for two reasons. First, to quantitate the separate motions, the subject must perform an “isovolume” maneuver as originally described by Konno and Mead or a separate “chest” and “abdomen” breath as reported from our laboratory. Many of the subjects in the present study, especially those with the asynchronous abdominal movements, had too great a degree of respiratory distress to carry out these maneuvers properly. Second, the identification and characterization of the pattern we have described is not dependent on the quantitative partitioning of tidal volume into chest and abdomen contributions. The relative heights of the chest and abdomen signals shown in Figures 1-3 therefore, cannot be interpreted as in-
indicating the relative contributions of the rib cage and diaphragm to the tidal volume. However, for any one signal, the deflections of the various components indicate relative degrees of linear motion. For example, in Figure 2 the larger upward deflection of the abdomen signal during expiration compared to inspiration, indicates a greater degree of outward linear motion of the abdominal wall during this period.

The chest wall may be considered as divided into two parts operating in parallel, namely, the rib cage and the abdomen-diaphragm. The latter in turn consists of two elements in series. Since the rib cage and the abdomen-diaphragm are in parallel, the volume change of the rib cage plus the volume change of the abdomen-diaphragm summate to produce the volume change of the entire respiratory system. Therefore, for a given movement of air the movement of one component of the system determines the movement of the other.

During inspiration the movement of the abdominal wall depends upon the downward descent of the diaphragm which displaces the abdominal viscera and causes the abdominal wall to bulge outward. At the same time, however, elevation of the rib cage increases the distance between the symphysis pubis and the costal margin tending to produce an inward movement of the abdominal wall. The net result depends upon the relative magnitude of these two opposing influences. Since normally the downward movement of the diaphragm is greater than the upward movement of the rib cage, the abdominal wall moves outward during inspiration even though approximately half of the downward movement of the diaphragm is cancelled out by the upward movement of the rib cage. All inspiratory muscles including the normal diaphragm act to elevate the rib cage. Toward the end of a maximal inspiration there is a sudden straightening of the thoracic spine which also elevates the rib cage. During expiration the rib cage and the spine revert to their resting position; this movement is a steady and slow one throughout expiration.

In normal subjects the abdominal muscles function in breathing only when the minute ventilation exceeds 40 liters. As the minute ventilation increases beyond this point, the abdominal muscles are active during increasingly larger parts of the expiratory cycle.

During inspiration there is a sudden straightening of the thoracic cage. This elevation is further accentuated toward the end of inspiration by straightening of the spine. This latter movement will be especially prominent in COPD patients breathing close to their maximal inspiratory position. The net result of these movements is a sharp inward movement of the abdominal wall toward the end of inspiration. Once inspiration is complete, the spine, rib cage, and abdominal wall return toward their resting positions and during expiration, as the thorax is gradually descending without corresponding ascent of the diaphragm, the net abdominal movement is outward.

If expiration no longer remains a passive phenomenon due to the loss of elastic recoil of the lung and airway obstruction, the abdominal muscles (primarily the rectus abdominus and the external and internal obliques) will contract. This contraction further depresses the thoracic cage bringing it closer to the symphysis pubis and also will add to the protrusion of the abdomen during expiration. Furthermore, in the presence of severe obstruction, contraction of the abdominal muscles makes the cross sectional contour of the upper abdomen more circular; this mechanism also will increase the anterior-posterior diameter.

This explanation, therefore, ascribes the abnormal abdominal movements to an ineffective diaphragm and full use of available intercostal and accessory muscles. An alternative explanation would be an active, double contraction of the diaphragm during each breathing cycle. To explore this possibility, electromyography of the rib cage and diaphragm was performed in one subject who demonstrated the full blown asynchronous breathing pattern.
The results are shown in Figure 3. The lower panel (B) demonstrates the asynchronous pattern. The upper panel (A) shows the electromyogram of the intercostals obtained from surface electrodes and the simultaneously secured electromyogram of the diaphragm obtained from an esophageal electrode (neither the scale nor the timing of the upper and lower panels correspond to one another). Inspiration and expiration as marked on the upper panel refer to the flow of air detected at the mouth with a pneumotachometer. Note that electrical activity of both muscle groups starts considerably before the actual inflow of air and that this inflow occurs over a relatively short part of the cycle. The electrical activity of the intercostals and diaphragm are perfectly synchronized with only one period of electrical activity of the diaphragm during each breathing cycle.

The patients who showed this asynchrony had statistically significant lower values for forced vital capacity and one-second forced expiratory volume when compared to the patients with synchronous movements. Their prognosis was poor, the mortality being significantly higher than those with a normal pattern. They were also more dependent upon assisted ventilation and more difficult to remove from the respirator than their normally breathing counterparts. Recognition of this breathing pattern should therefore help in the initial assessment of the patient and in planning the clinical management.

REFERENCES

1 Hoover CF: Definitive percussion and inspection in estimating the size and contour of the heart. JAMA 75:1625-1632, 1920