Observation of spontaneous respiratory interaction with artificial ventilation

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SUMMARY To compare the accuracy of clinical observation and detailed respiratory recordings in identifying infants at high risk of developing pneumothoraces 10 infants, with idiopathic respiratory distress syndrome, were studied at three different ventilator rates. All infants with synchronous respiration at fast rates were correctly identified by clinical observation. The clinical signs used to identify 'high risk' interactions—that is, active expiration and asynchronous breathing—were obvious respiratory efforts and a failure of improvement in oxygenation at increased rates. These criteria enabled correct identification of 'high risk' respiratory patterns on 15 (88%) of the 17 study occasions. These clinical criteria were then used as criteria for selective paralysis; no infant developed a pneumothorax during ventilation.

Spontaneous respiratory efforts during mechanical ventilation in preterm infants have been incriminated in the development of pneumothorax.1 2 Consequently attempts have been made to reduce the incidence of air leaks by using paralysing drugs; this was unfortunately unsuccessful.3-5 A possible explanation for this failure was the lack of selection of infants included in the studies. Preterm neonates breathe in one of four distinct interactions with artificial ventilation.4 Two of these—synchronous respiration5 and provoked augmented inspirations6—are advantageous. Inhibition of such interactions by paralysing drugs, which reduces their positive contribution to gas exchange, could increase the need for ventilation and hence result in pneumothoraces. Only one pattern of respiration—active expiration—was found to be significantly associated with the development of pneumothorax.4 When infants showing only this interaction were paralysed a highly significant reduction in the incidence of air leaks resulted.7

Detection of active expiration needed sophisticated respiratory recordings utilising expensive equipment and expertise to obtain the recordings and for their interpretation.7 It was thus desirable to be able to identify accurately such high risk infants by clinical observation alone. This was attempted in a subsequent trial.5 The criteria for selection for paralysis included 'struggling against the ventilator.' Unfortunately, although selective paralysis again produced a significant reduction in the incidence of air leaks,8 the magnitude of effect was less noticeable than in the previous study.7 This was possibly due to the less accurate method of detection of high risk infants.

We had previously noticed that comparison of the respiratory efforts of infants at two different ventilator rates enabled more reliable diagnosis of their interaction with artificial ventilation. The accuracy was improved if changes in transcutaneous oxygen concentrations were also considered. Infants whose respiratory efforts became less obvious at the faster rate in association with an upwards trend in transcutaneous oxygen concentrations were accurately described by the nurses as fighting the ventilator at the lower rate and synchronously respiring at the increased frequency. The purpose of the present study was to investigate whether, by studying infants at a series of ventilator rates, it was possible by clinical observation alone to identify correctly infants who would benefit from paralysis.

Patients and methods

Ten infants with a clinical diagnosis of the idiopathic respiratory distress syndrome were each studied at three different ventilator rates. Their mean birth weight was 1037 g (range 630–1500 g), and their mean gestational age was 27.5 weeks (range 25–31 weeks). Their mean age at the time of study was 19 hours and all were less than 3 days old. The infants were receiving intermittent positive pressure
ventilation (IPPV) by Sechrist ventilators. Before the study the ventilator rate was 30 breaths/minute. No infant had a pneumothorax or was receiving paralysing or sedating drugs at the time of the study.

Each infant was studied in his or her incubator while receiving full intensive care. The infants were ventilated at a succession of rates of 30, 60, 30, 120, and 30/minute, each rate being maintained for 20 minutes. There were no other changes in ventilator settings, mean airway pressure (MAP) was kept constant at the increased rate by altering flow as necessary. At the initial period of 30 breaths/minute and at 60 and 120 breaths/minute the infant’s respiratory interaction to ventilator inflation was recorded independently by two observers. One observer (AG) used detailed respiratory measurements9 and the other (research sister FG) used clinical observation and trends in transcutaneous oxygen. The two observers were unaware of each others results.

Respiratory efforts were recorded by an oesophageal balloon and catheter system attached to a pressure transducer (Validyne range ±50 cm H₂O). A pneumotachograph (Mercury Fi01L) attached to a pressure transducer (Validyne range ± 2 cm H₂O) was placed between the endotracheal tube and ventilator circuit and recorded flow changes both due to the infant and the ventilator. This signal was electronically integrated to give volume (Integrator model No 13–4615–70). Ventilator pressure changes were recorded from the infant’s side of the pneumotachograph (Validyne pressure transducer range ±50 cm H₂O). All the pressure transducers had a similar frequency of response, 63% rise time of 6 milliseconds, shown by a balloon burst experiment. Ventilator and oesophageal pressure, flow and volume changes were all recorded simultaneously on a Polygraph (Gould 2800S). The infant’s respiratory interaction with the ventilator was determined by analysis of the last 10 minute portion of the 20 minute recording at each ventilator rate.

The observer blind to the respiratory recordings but aware of the ventilator rate made a clinical judgment of the infant’s interaction with positive pressure inflation. This was based on observing the number of respiratory efforts in relation to ventilator frequency, the direction and magnitude of chest wall movement with relation to the ventilator cycle, and changes in transcutaneous oxygen with alteration in ventilator rate. Transcutaneous oxygen was monitored (Draeger Oxyrometer) throughout the study. The trend of change in transcutaneous oxygen was assessed by comparison, at each ventilator rate, of the average recording of the first and last five minutes of the 20 minute period.

At each ventilator rate the infant’s dominant respiratory interaction with the ventilator was placed into one of three groups. The dominant interaction was that shown on more than 80% of ventilator breaths.

(1) SYNCHRONY
(i) Respiratory recording: spontaneous inspiratory efforts coincided with the start of every or every second ventilator inflation.
(ii) Clinical observation: chest wall movement (upward deflection) occurred synchronously with ventilator inflation. As the rate was increased it became more difficult to distinguish chest wall movement due to the infant’s respiratory efforts or positive pressure inflation. Supportive evidence was an upwards trend in transcutaneous oxygen partial pressure at the increased rate.

(2) ACTIVE EXPIRATION
(i) Respiratory recording: during positive pressure inflation the oesophageal pressure recording showed the infant to be in expiration and this was associated with an expiratory flow.2
(ii) Clinical observation: poor chest wall expansion or a downward movement of the chest wall during positive pressure inflation. Supportive evidence was a failure to improve transcutaneous oxygen partial pressure by increasing ventilator rate.

(3) ASYNCHRONY
(i) Respiratory recording: the infant exhibited neither synchrony nor active expiration and/or spontaneous breaths occurred through out the ventilator cycle.
(ii) Clinical observation: spontaneous respiratory efforts had a poor relation to the timing of ventilator inflation. Despite the increasing ventilator rate the infant’s respiratory efforts were obvious and often distinct from chest wall movement due to positive pressure inflation. Supportive evidence was that an increased ventilator rate was not associated with an improvement in transcutaneous oxygen partial pressure.

To assess the accuracy of clinical observation in determination of the type of respiratory interaction, at the end of the trial, comparison was made of the results of the two observers for the 10 infants at each ventilator rate.

On completion of the study infants with synchronous respiration were subsequently ventilated at the slowest rate at which this was achieved.10 At fast
rates both asynchrony and active expiration had previously been used successfully as criteria for selective paralysis to reduce the incidence of pneumothoraces. As a consequence those infants continuing to show either interaction at increased ventilator frequencies, shown by respiratory recordings, were paralysed and subsequently ventilated at 60 breaths/minute.

Results

Respiratory recordings confirmed that most infants (eight out of 10) were actively expiring at the slowest rate. As ventilator rate was increased infants tended to breathe in synchrony with their ventilator; seven out of 10 at 120/minute (table 1).

When the results from the studies at all three ventilator rates were examined, clinical observation correctly identified all 13 occasions on which infants were synchronously respiring with their ventilator (table 2). No infant breathing either synchronously or asynchronously during ventilation was incorrectly identified as actively expiring by clinical observation. A change to synchronous respiration at the increased frequency was associated in all cases with an improvement in transcutaneous oxygen concentration (mean change 12 mm Hg, range 8–22).

On only five of 13 occasions during which infants were actively expiring was the interaction correctly identified by clinical observation, giving a sensitivity of 38% (table 2). At the slowest ventilator rate of 30 breaths/minute, five of the eight infants were correctly identified as actively expiring. At the faster ventilator rates, 60 and 120 breaths/minute, no infant actively expiring was identified by clinical observation, but six of the seven infants were labelled as asynchronous. Inclusion of asynchrony and active expiration as one group improved the sensitivity of clinical observation to 88%. Clinical observation correctly identified infants breathing in one of these two interactions on 15 of 17 occasions (table 2).

Three infants failed to achieve synchrony at any ventilator rate. As they continued to breathe asynchronously or actively expired they were paralysed after completion of the study. None of the other seven infants were paralysed during subsequent ventilation and during the acute phase of their respiratory illness the ventilator rate remained unchanged. Although non-paralysed infants were not restudied, as none of the 10 infants developed a pneumothorax, this suggests that if the appropriate fast rate of ventilation is chosen synchronous respiration is a stable interaction during the acute phase of the respiratory illness.

Discussion

These results confirm that active expiration is common particularly among immature infants who are ventilated at slow rates. When the ventilator rate is increased synchronous respiration tends to be induced and active expiration prevented. The faster ventilator rates more closely mimic the spontaneous breathing frequency of infants suffering from the respiratory distress syndrome and hence are more likely to induce synchronous respiration. Clinical detection of active expiration was only partially successful and particularly unsuccessful at faster rates. If, however, active expiration and asynchrony were classified together, clinical observation correctly identified infants belonging to this group on 15 (88%) of 17 occasions and no infant was incorrectly placed in this combined group. Thus if the criteria used for paralysis was a clinical observation of either asynchrony or active expiration, this would ensure inclusion of most infants at highest risk of developing pneumothoraces; but equally importantly no infant would unnecessarily be paralysed.

Table 1 Spontaneous respiratory interaction with positive pressure inflation at different ventilator rates

<table>
<thead>
<tr>
<th>Ventilator rate (breaths/minute)</th>
<th>30</th>
<th>60</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a) Respiratory recordings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active expiration</td>
<td>8</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Synchrony</td>
<td>0</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Asynchrony</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>(b) Clinical observation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active expiration</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Synchrony</td>
<td>1</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Asynchrony</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

The number of study occasions on which particular interaction was either (a) recorded or (b) observed is given at each ventilator rate.

Table 2 Comparison of the two observer’s results at each ventilator rate

<table>
<thead>
<tr>
<th>Ventilator rate (breaths/minute)</th>
<th>30</th>
<th>60</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interaction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active expiration</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Active expiration or asynchrony</td>
<td>9</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Synchrony</td>
<td>1</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Observations made with the help of respiratory recordings are in parentheses, observations blind to respiratory recordings are not in parentheses.
Observation of spontaneous respiratory interaction with artificial ventilation

Clinical detection of respiratory interaction was facilitated by observing trends in transcutaneous oxygen partial pressure with increased ventilator rate. All infants changing to synchronous respiration at the faster frequency had improvements in transcutaneous oxygen, as would have been predicted from our earlier results. The combination of 'obvious' respiratory efforts and a lack of improvement in transcutaneous oxygen at increased rates improved the accuracy of detection of infants asynchrony or actively expiring at the increased frequency and thus at high risk of developing pneumothoraces. These results suggest clinical observation of the infant's respiratory efforts and trends in transcutaneous oxygen monitoring, providing the infant is studied at different ventilator rates, can readily identify most infants who would benefit from paralysis.

Sister F Greenall was supported by Penlon Limited. Equipment used in this study was generously provided by Children Nationwide Medical Research Fund. We would like to acknowledge and thank Dr H Gamsu for his encouragement and support and the enthusiastic help of the staff of the neonatal intensive care unit. We thank Mrs Angela McPherson for secretarial help.

References


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Received 4 September 1987
Observation of spontaneous respiratory interaction with artificial ventilation.
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doi: 10.1136/adc.63.2.168

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