

## CURRENT PRACTICE

## Respiratory support using patient triggered ventilation in the neonatal period

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Over the last 30 years, there have been dramatic improvements in the survival rates of neonates requiring intermittent positive pressure ventilation. This has resulted from the introduction of ventilators specifically designed for use in babies weighing as little as 500 g and also from numerous studies attempting to optimise ventilatory techniques.<sup>1</sup> Nevertheless, even in the most skilled hands, babies still die during the acute phase of respiratory failure; pneumothoraces have not been abolished, and chronic lung damage produced predominantly by barotrauma and lung tissue hyperoxia is an increasing problem to neonatologists.<sup>2</sup>

**Respiratory activity during conventional intermittent positive pressure ventilation**

It is well established that in the immediate neonatal period, the pattern of ventilation selected by the respiratory centre in the brain stem is heavily modified by mechanical reflexes from the lung and chest wall<sup>3</sup>; such reflexes may be provoked by positive pressure inflation.<sup>4</sup> The Hering-Breuer reflex will limit inspiratory activity while at other times, Head's paradoxical reflex may stimulate the baby to make inspiratory respiratory efforts in response to intermittent positive pressure inflation.<sup>4</sup> If these were the only reflex responses then intermittent positive pressure inflation would always be associated with either apnoea or synchronous ventilation. Unfortunately, if the ventilator rate is too slow and the inspiratory time too long, reflex activity will stimulate the baby to make expiratory efforts during periods of ventilatory inflation.<sup>5, 6</sup> This greatly reduces the efficiency of ventilation and increases the risk of pneumothorax and barotrauma.<sup>4</sup> This problem can be reduced by paralysing all those 'fighting the ventilator',<sup>7</sup> but this is not without its complications. The baby is entirely dependent on adequate ventilator function, fluid retention is common, contractures may develop in the limbs,<sup>8</sup> and higher inflation pressures are often needed to compensate for the loss of the baby's albeit intermittent, contribution to ventilation.<sup>7</sup> An alternative, has been to tune the ventilator to the baby's own respiratory efforts, thereby inducing synchrony.<sup>9</sup> Unfortunately, this is not always possible,<sup>5</sup> and even when optimal settings are selected, asynchrony can still develop due to alterations in the disease severity, chemoreceptor drive, and in response to medical and nursing handling.

Theoretically, it should be possible to cir-

cumvent these problems if the baby's respiratory efforts are used to trigger the ventilator. This approach, patient triggered ventilation (PTV), has only recently become available for use in neonates.<sup>10</sup> In this technique, the peak inspiratory pressure, positive end expiratory pressure, and inspired oxygen, are set by the operator, but the rate is controlled by the baby's respiratory efforts. This has the potential advantage that the peak inspiratory pressure should be lower as the baby is contributing to transpulmonary pressure, and situations in which the baby is actively breathing out during a period of ventilator inflation should be eliminated. On theoretical grounds, this should reduce the incidence of pneumothorax and bronchopulmonary dysplasia.

**Triggering devices**

The performance of the triggering device is likely to be an important determinant of the success of PTV. The triggering device must have a high sensitivity and thus detect the maximum number of the infant's respiratory efforts. The trigger delay, the time from the onset of inspiration to the commencement of positive pressure inflation, should be as short as possible to ensure inflation occurs early in inspiration and does not continue into expiration. If the trigger delay is very long, the only method of preventing inflation extending into expiration and stimulating an adverse respiratory intervention<sup>4</sup> is to shorten inflation time to such an extent that the delivered volume is reduced. The trigger delay consists of two components, the time needed for the baby's respiratory efforts to reach the critical trigger level, which is dependent on the pattern of breathing adopted by the baby, and the response time or systems delay of the ventilator. Ideally, the systems delay time should not exceed 10% of the total inflation time; a systems delay of 36 ms permits a maximum ventilator rate of 83 breaths/min.<sup>11</sup>

Currently, changes in airway pressure, airway gas flow, and abdominal movement are used as trigger signals. Airway pressure is sensed by a pressure transducer connected by non-compliant tubing to a point on the patient manifold just proximal to the endotracheal tube. Airway gas flow can be detected using either a pneumotachograph or, more usually, paired thermistors mounted in the patient's manifold of the ventilator circuit. Abdominal movements are detected by a pneumatic capsule which, when taped onto the patient's abdominal wall, in the subxiphoid

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ternal position, senses changes in abdominal expansion which occur with respiratory efforts. Although successful in the short term, oesophageal pressure triggering devices have proved not to be suitable for long term use, as the continued presence of a balloon in the oesophagus stimulates peristalsis which interferes with the detection of the infant's respiratory efforts.<sup>12</sup>

#### Ventilator settings during PTV

The peak inspiratory pressure, the positive end expiratory pressure, and the fractional inspired oxygen are usually left unchanged when the baby is transferred from conventional ventilation to PTV and then subsequently modified depending on the response to PTV as determined by blood gas estimations. The inflation time does normally require to be shortened. Prolongation of the inflation time beyond 0.4 s reduces minute volume as the baby's spontaneous breathing rate is slowed, presumably via the Hering-Breuer reflex.<sup>13</sup> A long inflation time is also more likely to result in inflation extending into expiration, provoking active expiration.<sup>6</sup> A short inflation time below 0.2 s is not beneficial as this reduces the tidal exchange.<sup>14</sup> The optimal inflation time is determined by observation of the baby's respiratory efforts while receiving continuous positive airway pressure for up to 1 min.<sup>15</sup> Inflation time should be about equal to the spontaneous inspiratory time after deduction of the systems delay; this ranges between 0.04 and 0.1 s depending on the ventilator selected. The inflation time is then reduced if necessary until the baby's respiratory efforts are indistinct from the ventilator inflation.<sup>15</sup>

As preterm babies have a tendency to apnoea, particularly when unwell, it is essential to have a minimum ventilator back-up rate to ensure continuity of respiratory support. This is achieved by either dialling in a maximal permitted expiratory time or a minimum ventilator rate. Thus 'back-up' ventilator rate is usually selected in conventional mode immediately before conversion to patient triggered mode. If the baby fails to trigger the ventilator by the end of the selected expiratory time, a single positive pressure inflation will occur.

#### Synchronous intermittent mandatory ventilation

One problem associated with PTV is that the operator has no control over the ventilatory rate, other than by altering the inspiratory time. Thus, during weaning, only the peak inspiratory pressure, the positive end expiratory pressure, and inspired oxygen can be reduced. A recent improvement has been to build in a variable refractory period after the ventilator has fired, essentially inactivating the trigger for a number of the baby's own respiratory efforts. It is then possible to reduce the ventilator rates progressively by increasing this refractory period.<sup>16</sup>

#### Clinical trials on PTV

One study compared PTV delivered by the

modified SLE 250 ventilator using the MR10 pneumatic capsule, and the airway pressure triggering systems.<sup>17</sup> The median trigger delay of the airway pressure sensor was 200 ms compared with 300–550 ms with the MR10. As a result, synchrony occurred more frequently using the airway pressure trigger, leading to a significantly greater tidal exchange. The airway pressure trigger also had a much greater sensitivity detecting up to 100% of the infant's respiratory efforts, compared with 70–90% from the MR10 respiration monitors.<sup>17</sup> The commercially available systems now available undoubtedly function better: preliminary studies indicate that, for example, the Draeger Baby Log and SLE HV 2000 have trigger delays of less than 100 ms in preterm babies with the respiratory distress syndrome.<sup>18 19</sup>

There have now been a number of studies attempting to define the optimal role of PTV. This is usually unsuccessful in infants of less than 28 weeks' gestation.<sup>15</sup> Such infants rapidly develop a metabolic acidosis; their respiratory efforts are irregular and often of insufficient magnitude to trigger the ventilator consistently. PTV also failed in nine of 13 infants greater than 27 weeks' gestation, but less than 24 hours of age.<sup>20</sup> In contrast, PTV has provided an alternative to conventional ventilation in babies greater than 28 weeks' gestation after the first 24 hours of age.<sup>15</sup> One study suggested that PTV may reduce the incidence of pneumothorax,<sup>21</sup> but unfortunately this used historical controls and there is no evidence from randomised trials to support this contention. PTV has also been attempted in those very immature infants who require ventilation beyond the second week of life due to chronic lung disease, but rarely provided a satisfactory alternative to conventional ventilation. In these babies, PTV was only successful in three out of 16 infants; the remaining 13 were either asynchronous or made only irregular respiratory efforts with deterioration in blood gases after only one hour.<sup>22</sup>

#### Prediction of failure of PTV

Gestational and postnatal age are important determinant factors of the PTV outcome.<sup>15 22</sup> Studying infants for only one hour on PTV provides useful information to assess if PTV will be successful in the long term.<sup>15</sup> Failure of PTV is likely to occur in infants whose oxygenation does not increase after one hour, compared with a similar period on conventional ventilation. A further indicator of failure is a triggering rate which is slow in relation to the infant's gestational age,<sup>23</sup> and an asynchronous respiratory interaction.

#### Summary

There are now a number of purpose built patient triggered ventilators for use in the newborn. These ventilators are triggered either by air flow or airway pressure changes, their triggering devices all have very high sensitivity and short systems delay. They all have the advantage that they perform well without in-

advertent positive end expiratory pressure at the fast ventilator rates frequently triggered by immature infants. Despite all these improvements in both ventilator and trigger performance, PTV is still frequently unsuccessful in the most immature infants. We must conclude that the nature of the extremely preterm infant's respiratory efforts in the acute stage of respiratory illness may mean that PTV is unlikely to provide the optimal mode of respiratory support for this group of patients. Short term studies have suggested that those infants with relatively mild respiratory distress syndrome showed the greatest improvement in blood gases. These results suggest that PTV may have its most efficacious role during weaning and in the larger, more mature baby who is 'fighting the ventilator'.

#### Correction

In the article entitled 'Patient triggered ventilation using a flow triggered system' (M F Hird, A Greenough, *Arch Dis Child* 1991;66:1140-2) an incorrect model number of the SLE ventilator was given, the trigger delay of 200-250 ms applies to the SLE 250 and not the SLE HV 2000.

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