Step by Step Guide

VENTILATION IN THE NICU

SLE the UK's leading supplier of infant ventilators, namely the world beating **SLE2000** with its unique patented valveless system

&

The revolutionary **SLE2000 HFO** developed from the SLE2000 with the ability to operate as a pure oscillator (with a sinusoidal wave form) or add oscillations of adjustable amplitude to either inspiratory or expiratory phase of ventilation or a combination of both.

SLE2000 INFANT VENTILATOR CE 0120

SLE2000 HFO INFANT VENTILATOR CE 0120

For further information please contact

SLE

Twin Bridges Business Park
232 Selsdon Road
South Croydon Surrey CR2 6PL UK
Tel+44(0)181-681 1414 Fax+44(0)181-649 8570

in association with

JNN JOURNAL OF *neonatal* NURSING

VENTILATION IN THE NICU

Approximately 1% of all newborns require some form of respiratory support. This can be life saving, but it is clear, if inappropriately applied, can increase morbidity.

Over the last 20 years the survival rates of infants who require respiratory support have increased. Sadly some infants do, however, suffer morbidity; including pneumothorax, intracerebral haemorrhage and chronic lung disease. As a consequence, research has been directed at improving conventional respiratory support and developing new techniques such as high frequency oscillation (HFO).

Techniques

Conventional ventilation (rates 0-150 bpm)

Conventional neonatal ventilation is pressure rather than volume limited, therefore, if the infant's lungs become stiffer (less compliant), a smaller volume is delivered for the same pressure. The patient's respiration may be supported by a constant pressure, that is continuous positive airways pressure (CPAP). For infants with more severe disease positive inflations are applied on top of CPAP which is then called positive end expiratory pressure (PEEP). This mode is either called intermittent mandatory ventilation (IMV) or intermittent positive pressure ventilation (IPPV) depending on the rate at which the positive pressure inflations are delivered (Fig 1).

During respiratory support, despite use of sedation, most babies will make breathing efforts. Studies have demonstrated that some of these breathing efforts are detrimental, whereas others are useful. Some infants actively breathe out against each positive pressure inflation (active expiration), which causes pneumothoraces. This outcome can be avoided by administering a neuromuscular blocking agent such as pancuronium or alternatively the ventilator rate can be increased up to 120 breaths per minute (bpm) to mimic the infant's own breathing frequency. At rates of 60-120 bpm, known as high frequency positive pressure ventilation (HFPPV), infants frequently breathe synchrononously with the ventilator, that is inflation and inspiration coinciding. Synchronous ventilation is associated with improved oxygenation.

Triggered ventilation

During triggered modes of ventilation, mechanical inflations are delivered in response to the infant's respiratory efforts. With each breath the infant generates a change in airway flow or pressure or body movement. This can be sensed by a triggering device and if a critical level is exceeded a positive pressure inflation is delivered to the infant. Triggered ventilation can be delivered in two modes. During patient triggered ventilation (PTV) every spontaneous breath exceeding the critical level triggers a positive pressure inflation; if a baby is breathing at 80 bpm then 80 positive pressure inflations could be delivered to the infant (Fig 2). The second mode is synchronous intermittent mandatory ventilation (SIMV) during which the maximum number of breaths which can be triggered is the "dialled in" SIMV rate; even if the infant breathes at a rate of 80 bpm, if the SIMV rate is 20 bpm the maximum number of triggered breaths is 20 bpm (Fig 2).

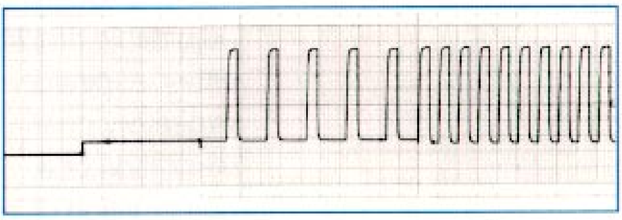

Fig 1. Recording of airway pressure changes during (left) CPAP, (middle) IMV and (right) IPPV.

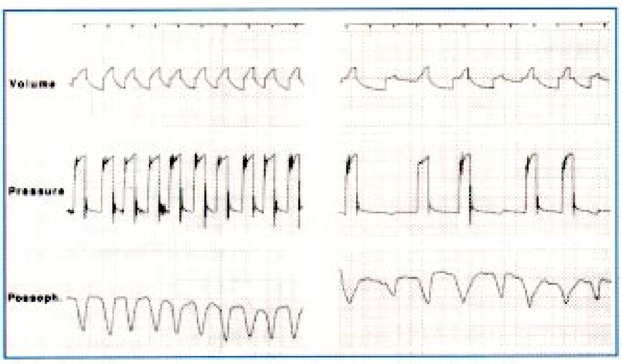

Fig 2. Recording of volume, airway and oesophageal pressure during PTV (left) and SIMV (right).

Written by

Anne Greenough
MD, FRCP, DCH
Professor of Clinical Respiratory Physiology

Jennifer Kemp
RGN/RSCN, ENB405, 998 and A19 Advanced Neonatal Nurse Practitioner

Frances Greenall
RM, RN, ENB400, C&G 730
Neonatal Lecturer
Practitioner of the Children Nationwide Regional Neonatal Intensive Care Centre, King's College Hospital, London

JNN Journal of neonatal nursing

High frequency oscillation (HFO)

During HFO, small tidal volumes are delivered at frequencies between 5 and 15 Hz (that is 5-15 per second). Unlike other forms of respiratory support, there is active inflation and active expiration, that is air is pushed in and sucked out of the lungs. HFO is usually delivered against a background of a constant mean airway pressure (MAP) (Fig 3), but certain machines allow a combination of "conventional" and oscillatory ventilation, such that oscillations may be delivered only during PEEP or PIP or throughout the ventilator cycle. During HFO oxygenation is controlled, as in conventional ventilation, by the inspired oxygen concentration and MAP level. Carbon dioxide elimination, as in conventional ventilation, is related to the tidal volume delivery; this is primarily controlled by the oscillatory amplitude. In addition, during HFO carbon dioxide elimination is enhanced by decreasing frequency.

Advantage and disadvantages of different modes of ventilation

Conventional ventilation

Advantages

This form of respiratory support has been used on NICUs for the last 20 years. It has been extensively examined in numerous research studies. HFPPV compared to ventilation at rates of 30-40/minute reduces the incidence of air-leak. No study, however, has demonstrated that HFPPV impacts on chronic lung disease.

Disadvantages

Despite attempts to optimise ventilator rate, use of antenatal steroids and postnatal surfactant, approximately 25% of infants supported on conventional ventilation remain asynchronous and require additional or alternative therapeutic strategies if pneumothorax is to be avoided. In addition, a significant proportion of infants have severe respiratory failure and require high inspired oxygen concentrations and peak inspiratory pressures putting them at risk of chronic lung disease.

Triggered ventilation

Advantages

Randomised studies have demonstrated that, in certain birthweight groups, PTV may reduce the duration of ventilation and oxygen dependency beyond 36 weeks postconceptional age. In addition, PTV reduces the duration of weaning.

Disadvantages

There is no consensus regarding the optimum triggering device. Comparative studies suggest that airflow triggers are less useful in infants with chronic lung disease; in very prematurely born infants (<28 weeks), all triggering devices perform less well.

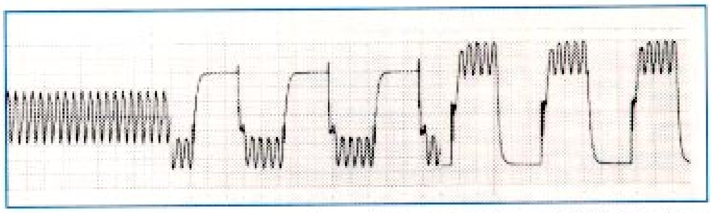

Fig 3. Recording of airway pressure changes during (left) HFO on MAP/CPAP, (middle) HFO on PEEP only and (right) HFO on PIP only

High frequency oscillation

Advantages

HFO rescues approximately 50% of infants with severe respiratory failure referred for extracorporeal membrane oxygenation (ECMO). In preterm infants with severe respiratory distress syndrome (RDS) HFO improves oxygenation if a "high volume" strategy is used, that is the MAP is increased to recruit atelectatic alveoli and optimise lung volume. It remains controversial whether HFO reduces the incidence of chronic lung disease.

Disadvantages

HFO has only been introduced into the UK in the last five years and therefore experience is limited. Two randomised studies have suggested HFO may increase intracerebral haemorrhage, but this has not been confirmed. Inexperience is likely to increase the risk of side-effects.

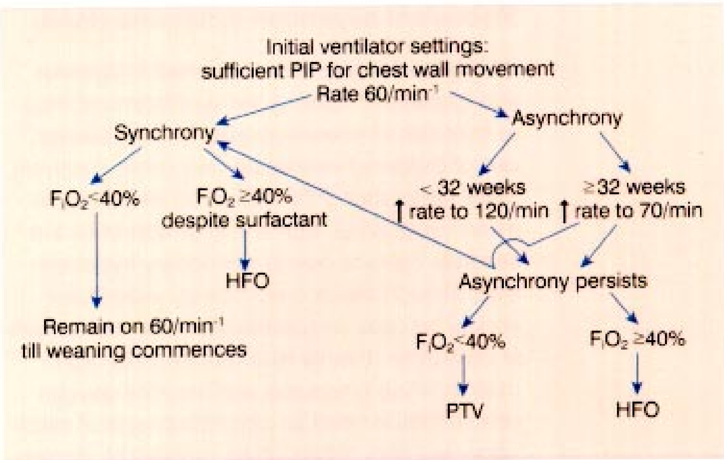

Fig 4. Ventilatory management of acute RDS.

Application of ventilation modes to different respiratory disorders

Respiratory distress syndrome

The majority of infants with RDS should have received antenatal steroids and have relatively mild RDS which is further improved by the administration of postnatal surfactant replacement therapy. Such infants can be stabilised on conventional ventilation, taking care to manipulate rate so that the infant breathes synchronously (Fig 4). Recovery from RDS is indicated by a requirement for lower pressures and inspired oxygen concentration, then weaning should be undertaken on PTV (Fig 5).

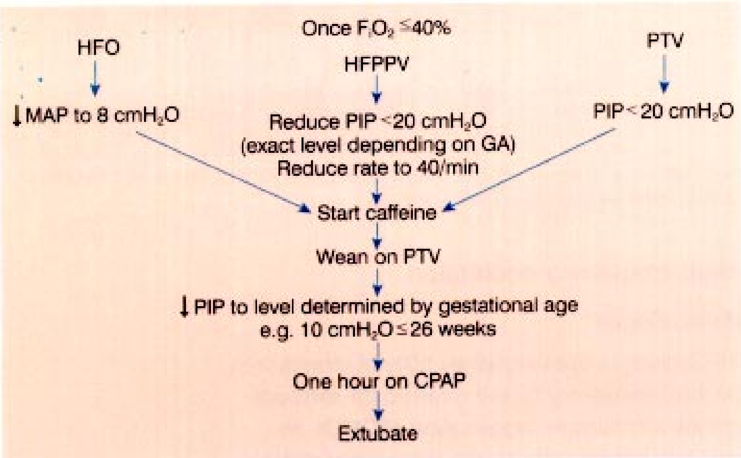

Fig 5. Weaning from ventilatory support.

A small proportion of infants with RDS, usually those who have not received antenatal steroids because of a precipitous delivery, eg following a large antepartum haemorrhage, develop severe respiratory failure. Such infants have solid, atelectatic lungs, with a "whiteout" appearance on their chest radiograph. These infants should be put on HFO using a high volume strategy ie increasing MAP to improve oxygenation. Once the infant's respiratory failure improves, the inspired oxygen should be reduced first down to 0.30 then the MAP decreased. Further weaning can be achieved on PTV (Fig 5).

Meconium aspiration syndrome (MAS)

If MAS is relatively mild, the infant is vigorous and capable of fighting the ventilator and thus at high risk of pneumothorax. In such babies, use of triggered ventilation may avoid paralysis, SIMV rather than PTV should be employed to avoid hypocarbia. Some infants with MAS are severely hypoxic due to pulmonary hypertension. In such cases a pulmonary vasodilator should be used in combination with conventional ventilation. Infants who require both high peak inflating pressures and inspired oxygen concentration need an alternative form of respiratory support. If their chest radiograph demonstrates symmetrical lung disease, they usually respond to HFO, but if their disease is asymmetrical or they deteriorate on a combination of HFO and a pulmonary vasodilator, then extracorporeal membrane oxygenation (ECMO) should be considered.

Airleak

Infants who develop pneumothoraces during any form of respiratory support require analgesia and an underwater sealed drain put on suction. If on conventional ventilation, paralysis is required to prevent further pneumothoraces, then the ventilator rate should be reduced to 60 bpm to prevent air trapping . If the pneumothorax develops on HFO, then a "low volume" strategy should be used; MAP lowered and the inspired oxygen increased as necessary. The development of pulmonary interstitial emphysema (PIE) is always worrying, further barotrauma should be prevented by limiting the applied pressures.

Chronic lung disease (CLD)

Increasing PEEP to 6cmH_2O and limiting ventilator rate to 60 bpm provides optimum gas exchange for infants with type I chronic lung disease (that is with low volume lungs). Infants with type II chronic lung disease or bronchopulmonary dysplasia (BPD) (that is, cystic areas in the lungs) are now rare. Such infants are extremely difficult to ventilate. They require sedation and often paralysis to prevent "cyanotic attacks". To prevent further gas trapping, long expiratory times and low levels of PEEP should be tried.

Conclusion

A variety of of ventilation techniques are currently available. No technique is optimal for all neonates. A thorough knowledge of neonatal respiratory pathophysiology (Tables 1 and 2) is required if the techniques are to be employed most efficaciously.

Diagnosis	Lung function abnormality
RDS	↓ compliance, ↓ lung volume
MAS	↑ resistance, may have gas trapping
PIE	↑ resistance, ↓ compliance, ↑ gas trapping
Type I CLD	±↑ resistance, ↓ lung volume
Type II CLD	↑↑ resistance, ↑↑ gas trapping, ↓ compliance

Table 1. Lung function abnormalities related to respiratory diagnosis.

Lung function abnormality	Ventilatory manoeuvre to improve gas exchange
Low compliance	↑ PEEP, ↑ PIP, ↑ T_i
Low lung volume	↑ PEEP
High resistance	↓ PEEP, ↑ expiratory time
Gas trapping	↓ PEEP, ↑ expiratory time

Table 2. Ventilatory manoeuvre to improve gas exchange related to lung function abnormality.

References

Greenough A, Greenall F. (1988). Observation of spontaneous respiratory interaction with artificial ventilation. *Arch Dis Child* 1988; **63**: 168-171.

Greenough A. (1995). Patient triggered ventilation. *Pediatr Pulmonol* 1995; Suppl 11: 98-99.

Greenough A. (1994). High frequency oscillation. *Eur J Pediatr* 1994; **153** (Suppl 2): S2-S6.