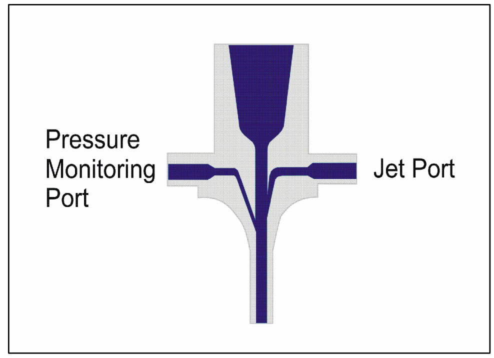
bunnell
INSPIRED INFANT CARE

WHAT is the LifePulse
High Frequency Ventilator

Description:

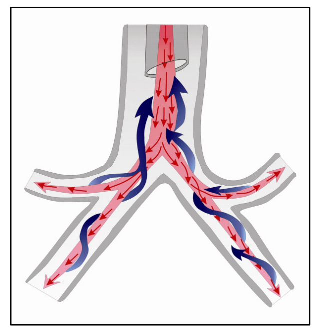
The LifePulse is pressure-limited and time cycled with adjustable PIP and rate. Inspiratory time (I-time) is kept as short as possible (0.02 sec). Expiration is passive.



The LifePulse delivers small tidal volumes (V_T) at rapid rates via a special ET tube adapter with built-in jet nozzle. Connecting this adapter to a patient's endotracheal or tracheotomy tube enables tandem use of CMV.

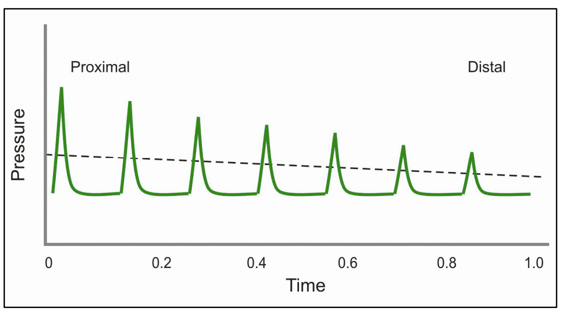
Gas flow is feedback-controlled by matching monitored PIP with set PIP. Monitored servo-controlled driving pressure (Servo Pressure) is used to detect changes in lung compliance and resistance and mishaps such as accidental extubation, pneumothorax, bronchospasm, etc.

Ventilation Controls:



Pressure amplitude (PIP-PEEP) produces V_T and controls $PaCO_2$. $V_T \approx 1$ mL/kg body mass is about half the size of anatomic dead space, because the LifePulse high velocity inspirations penetrate *through* the dead space instead of pushing the resident deadspace gas ahead of fresh gas as we do when we breathe normally. Expired gas cycles out in a counter-current helical flow pattern around the gas jetting in, which facilitates mucociliary clearance in the airways.

PIP may be set as high as that used during CMV. However, because inspirations are so fast and brief, PIP falls quickly as HFV breaths penetrate the airways, and peak *alveolar* pressure is much lower than peak *airway* pressure.



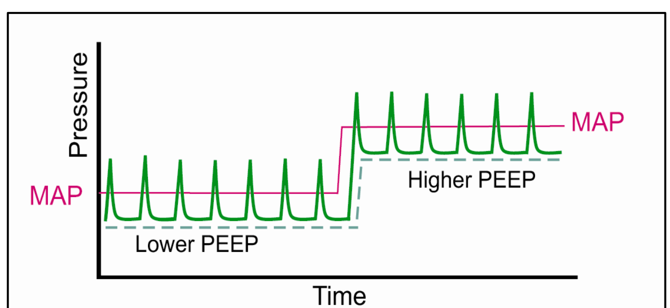
The LifePulse uses passive exhalation. Thus, airway pressure at end-expiration, PEEP, is constant throughout the lungs, as long as rate is set slow enough to avoid gas trapping.

Rate is usually set 10 times faster than CMV rates, in proportion to patient size and lung time constants (lung compliance x airway resistance). Keeping I-time constant at its shortest value (0.02 sec) allows exhalation time (E-time) to be proportionally longer at lower LifePulse rates, which aids in the treatment of larger patients and infants with restricted or obstructed airways.

At 240 bpm (4 Hz) for example, I:E = 1:12. Conversely, smaller patients may be treated at rates up to 660 bpm (11 Hz) where I:E = 1:3.5. Lowering rate may require raising PIP to maintain $PaCO_2$, because LifePulse V_T is independent of rate. But, LifePulse V_Ts are still ~10 times smaller than CMV V_Ts because of the 0.02 sec I-time.

Oxygenation Controls:

CMV settings control oxygenation. CMV at 2-5 bpm facilitates alveolar recruitment with its larger V_Ts. PEEP is the primary determinant of mean airway pressure (MAP) and lung volume.



PEEP is the primary control for MAP and oxygenation

Optimal PEEP may be found using CMV breaths and pulse oximetry. MAP on CMV prior to starting the LifePulse is reproduced at start-up by raising PEEP 1-2 cm H_2O initially. Patients are then stabilized with CMV = 5 bpm and F_IO_2 adjusted to produce appropriate SaO_2. CMV is then switched to CPAP mode, and PEEP is increased until SaO_2 is restabilized. Thus, CMV breaths are usually used only temporarily.

This approach produces an HFV version of “lung protective ventilation”, where alveoli are opened, kept open with appropriate PEEP (usually in the range of 8 - 10 cm H_2O), and ventilated as gently as possible. Gas for the patient’s spontaneous breathing is provided by the CMV in CPAP mode.

Gas Trapping Considerations:

Gas trapping occurs when tidal volumes have insufficient time to exit the lungs. Thus, larger CMV tidal volumes represent a greater threat of gas trapping compared to much smaller HFV breaths. CMV rate should therefore be reduced before HFV rate whenever there are indications of gas trapping, such as hyperinflation on chest xray or when the LifePulse monitored PEEP exceeds CMV set PEEP. If hyperinflation persists once the CMV is in CPAP mode, decrease the LifePulse rate in 60 bpm increments to improve the I:E ratio and lengthen the exhalation time.

Tidal volumes necessary to produce adequate ventilation at high rates are very small, and lung compliance is often poor in very low birth weight infants, so gas trapping is unlikely to occur with the LifePulse. However, the maximum rate of 660 bpm is rarely used even in preemies weighing less than 1000 grams. Most LifePulse users limit rate to 540 bpm (9 Hz) where I:E = 1:4.5. The minimum I-time of 0.020 sec usually works best for all patients at all rates.

Applications:

While some clinicians use the LifePulse for premature infants with uncomplicated RDS, it is most often used to rescue infants and children with lung injury. PIE is the most common indication for the LifePulse, because it automatically improves ventilation/perfusion matching and facilitates healing by reducing mechanical ventilation of the most affected areas of the injured lungs.

PIE is characterized by inflamed airways with high airway resistance that creates gas trapping, pulmonary overdistension, and alveolar disruption when other forms of mechanical ventilation are used. Since high airway resistance deters high velocity inspirations, resolution of PIE is much more likely using the LifePulse.

Other airleaks, meconium aspiration and other pneumonias (especially those accompanied by excessive secretions), congenital diaphragmatic hernia, and PPHN are other common applications of the LifePulse in NICUs, while trauma and severe pneumonia are typical applications in PICUs. Some institutions also use the LifePulse during and after pediatric cardiac surgery (e.g., Fontan procedure), especially when complicated by respiratory failure.

A pilot study using the LifePulse was initiated in 2006 for “evolving” chronic lung disease in prematurely born infants at 1 to 3 weeks of age. Strategy for these patients is low LifePulse rate (240 bpm), no CMV breaths, and moderate PEEP (~8 cm H_2O). [Note: PEEP is needed to keep airways as well as alveoli open. Reducing PEEP to lessen gas trapping may make matters worse by allowing small airways to collapse during exhalation.] Previous randomized controlled trials support use of the LifePulse for uncomplicated RDS, RDS complicated by PIE, and PPHN.

Complications:

Hyperventilation with the LifePulse is associated with increased incidence of cystic periventricular leukomalacia in premature infants with RDS. A single center study revealed such increased adverse effects when the LifePulse was used with low PEEP (5 cm H_2O) where hyperventilation and inadequate oxygenation occurred during the first 24 hours of life. (Inadequate PEEP leads to using higher PIP to generate more MAP, which causes hyperventilation.)

Servo Pressure:

Servo Pressure auto-regulates gas *flow* to the patient to keep monitored PIP = set PIP. The following examples are typical of what automatically set upper and lower Servo Pressure alarms indicate.

<u>Servo Pressure Increases with:</u>

- Improving lung compliance or airway resistance, which can lead to hyperventilation
- Leaks in ventilator circuit leading up to the patient

<u>Servo Pressure Decreases with:</u>

- Worsening lung compliance or airway resistance (e.g., bronchospasm), which can lead to hypoxemia
- Obstructed ET tube (e.g., from a mucus plug)
- Accumulating secretions at the end of the ET tube (i.e., patient needs suctioning)
- Tension pneumothorax
- Right mainstem intubation

Monitoring Servo Pressure helps you determine if the patient is getting better or worse after you administer surfactant, make a change in ventilator management strategy or patient repositioning.

For more information, visit www.bunl.com or call us at 800-800-4358.