High-Frequency Jet Ventilation

HFJV uses a jet injector to introduce a small volume of rapidly moving gas into the neonate's airway. Exhalation of gases occurs passively, as a result of the elastic recoil of the lung.[48] Tidal volumes, although difficult to measure accurately, are thought to be slightly greater than ADS.[27,28]

In the U.S., as noted earlier, HFJV is provided by the Bunnell Life Pulse, a microprocessor-controlled, positive pressure–limited, time-cycled, high-frequency ventilator. The jet pulses (breaths) are delivered from a valve box located close to the patient (Figure 12-8). The frequency range of these pulses is 240–600 breaths per minute.[49] This valve box also contains the transducer that monitors airway pressure. The valve box is connected to the patient through a specialized triple-lumen endotracheal tube adapter (LifePort endotracheal tube adapter, Bunnell, Inc., Salt Lake City, Utah) (Figure 12-9). One lumen in this adapter provides jet flow, the second one produces background gas flow, and the third lumen allows for pressure monitoring. To establish a patient on HFJV, it is necessary to change the endotracheal tube adapter, but reintubation of the patient is not required. The Life Pulse ventilator provides HFV in tandem with a CMV device. The CMV device provides the PEEP and background CMV breaths (sighs) as needed.

Ventilation (carbon dioxide removal) is mainly determined by the amplitude or size of the breath as measured by ΔP. The size of these jet pulses (tidal volume) is controlled by the jet PIP and length of inspiration. Inspiratory time is generally held at 20 milliseconds. Therefore, tidal volume is not affected by rate changes unless inspiratory time is specifically changed. Lower peak and mean airway pressures are needed for CO_2 removal with HFJV than with HFOV.[50–53]

Paw, a more complex calculation, is determined by the interrelationship of numerous factors, including jet PIP and frequency, and the rate, inspiratory time, and PEEP provided by the tandem conventional breaths.[6] The gas flow to create the jet impulses is governed by a microprocessor-controlled pressure regulator that adjusts to meet the operating conditions. This gas flow, or servopressure, changes in response to lung volume, respiratory compliance, or airway resistance. In the absence of an air leak in the system, rising servopressure usually indicates improved compliance. A drop may indicate increased airway resistance, decreased compliance, or tension pneumothorax.[54] The key concepts for HFJV use are as follows:

- Oxygenation is related to Paw, CO_2 removal, and tidal volume.
- Generally, HFJV allows use of a lower Paw and PIP than does CMV.
- The HFJV (Bunnell Life Pulse) requires use of a background CMV device to provide PEEP. The CMV device also sustains inflations (sighs) when recruitment of an atelectatic lung is needed.
- The HFJV can utilize an “elevated” or “high” Paw strategy to support oxygenation and optimal lung volumes.
- HFJV requires a specific type of endotracheal tube adapter.

Clinical Strategies

When dealing with an infant with restrictive lung disease and air leak syndromes such as pulmonary interstitial emphysema (PIE) and pneumothorax, the goal in using HFJV is to use less PIP and Paw, to allow the air leaks to heal. Starting with a PIP at the same level as that used for CMV is suggested. The Paw should be the same or 1–2 cmH_2O less to support oxygenation. The PEEP can be the same or greater by 1. The HFJV rate is usually started at 420 breaths per minute.[36]

As the infant is placed on HFJV, the CMV is weaned to a rate of 5 and, if possible, an HFJV PIP less than that used for CMV. To avoid further injury in patients with air leak injury, lower tandem CMV rates (down to 0), or use only continuous positive airway pressure (CPAP) when oxygenation is adequate.[36] The CPAP levels must be high enough to stabilize open alveoli, but not so high as to prevent healing. The risk of delayed air leak healing from the CPAP level needed to support oxygenation must be balanced against the trauma of the CMV rate (large tidal volume breaths).

Severe atelectatic disorders, such as respiratory distress syndrome (RDS), may also benefit from HFJV as a way to reduce airway injury. These atelectatic disorders require a different strategy than restrictive or obstructive lung diseases. The PIP may be slightly reduced or the same as the CMV setting. The PEEP setting is usually increased to the range of 6–8 cmH_2O pressure.[55] The HFJV rate will be 420 breaths per minute.

Again, the infant is weaned from background CMV support, but if oxygenation falls, the CMV PIP may need to be slightly higher than the HFJV PIP. This is to help recruit atelectatic air spaces. The CMV support, usually PIP, is reduced as rapidly as lung volume stabilization allows; then the HFJV PIP is reduced as tolerated. However, to prevent atelectasis, PEEP may need to remain elevated as PIP is decreased.

Obstructive disorders, such as meconium aspiration syndrome (MAS), can be treated with HFJV. The device is used to support gas exchange and also creates vibratory energy, which facilitates debris removal.[10] Until stabilized, the patient may require high HFJV and background settings. Often, once lung volume is restored, the infant can be effectively ventilated (or hyperventilated) with HFJV at a lower PIP.

It is essential to assess the patient constantly for gas trapping. Sufficient expiratory time is required to avoid significant gas trapping. Expiratory time can be gained by lowering the HFJV rate (to as low as the 240–360

TABLE 12-3
Matching Ventilator Strategy and Disease Process

Disease Process	Pathophysiology	Strategy/Goals	Initial Settings	Weaning
Air leak syndrome (PIE, pneumothorax)	PIE: gas interstitium compressing alveoli, airways, and pulmonary venules Pneumothorax: loss of V_T through chest tube	Minimize distending and peak pressure, accept lower PaO_2, higher FiO_2, and $PaCO_2$, target lower lung volume.	Drop PIP by 10–20% from value on DV; PEEP 4–6 cmH_2O; avoid background sigh if severe PIE	Lower PIP aggressively. Look for atelectasis, and increase PEEP as needed.
Severe uniform lung disease (RDS)	Atelectasis, hypoxemia, lungs highly susceptible to volutrauma and oxygen exposure	Recruit lung volume, achieve optimal expansion, avoid overventilation. Use frequent x-rays to guide management.	PIP initially same as CV, but must be dropped quickly; once lung volume is recruited, PEEP 6–9 cmH_2O, depending on FiO_2	Wean FiO_2 before Paw; (may need to increase PEEP to avoid drop in Paw when PIP is lowered).
Nonuniform disease (MAS)	Uneven aeration, risk of gas trapping, surfactant inactivation, inflammation, high risk of air leak (Atelectasis or gas trapping may predominate.)	Tailor strategy to predominant pathophysiology. Avoid gas trapping, optimize lung volume.	Lower frequency (300–360) PIP to achieve minimal acceptable PCO_2. Moderate PEEP 5–8 cmH_2O	Lower PIP and use PEEP to avoid loss of lung volume.
Chest wall restriction (severe NEC, repaired gastroschisis)	Restricted chest and/or diaphragmatic movement, atelectasis, hemodynamic impairment	Recruit lung volume, avoid atelectasis, minimize adverse hemodynamic effects.	Adjust PIP to achieve adequate chest wall movement. Sufficient PEEP to maintain FRC (usually 6–8 cmH_2O)	Wean PIP to avoid hypocarbia. Maintain Paw with PEEP.
Lung hypoplasia (CDH)	Small, atelectasis-prone lungs, susceptible to volutrauma, pulmonary hypertension	Gently recruit lung volume, avoid overexpansion, minimize adverse hemodynamic effects.	Set PIP at lowest level to achieve adequate ventilation. Fast rates okay as time constants are short. Sufficient PEEP to maintain FRC (usually 6–8 cmH_2O)	Wean carefully but fast enough to avoid overexpansion and air leak.
Obstructive disease (BPD)	Long time constants, risk of gas trapping, nonuniform inflation	Achieve adequate gas exchange with minimal pressures, optimize lung volume, improve uniformity of inflation.	Lower frequencies due to long time constants, moderate PEEP to optimize gas distribution and splint airways open	Wean slowly; rapid improvement is not anticipated.

Key: BPD = bronchopulmonary dysplasia; CDH = congenital diaphragmatic hernia; CV = conventional ventilation; FRC = functional residual capacity; Paw = mean airway pressure; MAS = meconium aspiration syndrome; NEC = necrotizing enterocolitis; PEEP = positive end-expiratory pressure; PIE = pulmonary interstitial emphysema; PIP = positive inspiratory pressure; RDS = respiratory distress syndrome; V_T = tidal volume.

Adapted from: Keszler M. 2005. High-frequency jet ventilation. In *Intensive Care of the Fetus and Neonate,* 2nd ed., Spitzer AR, ed. Philadelphia: Mosby, 664. Reprinted by permission.

breaths per minute range).[37] This is indicated by an increasing I:E ratio.

Weaning from HFJV has not been systematically studied. In general, the therapy is used during the acute phase of the disease. The air leaks, if present, should be resolved for one to two days before weaning. It is recommended that Paw not be decreased until the neonate is requiring less than 40 percent FiO_2. Methods of weaning vary, but they usually involve decreasing the tidal volume (PIP) in low birth weight infants to 12 cmH_2O pressure and Paw to 6–8 cmH_2O prior to extubation.[55] Table 12-3 presents additional suggestions for managing specific diseases with HFJV.