# high frequency jet ventilation

## general

- High-frequency ventilation is a mode of mechanical ventilation in which small tidal volumes are delivered at high supraphysiologic frequencies.
- types of high-frequency ventilation include:
(i) high-frequency positive-pressure ventilation,
(ii) high-frequency percussive ventilation,
(iii) high-frequency jet ventilation, and
(iv) high-frequency oscillatory ventilation.

- The mechanics of high-frequency ventilation make it particularly well suited to protecting the lung, and there is growing clinical experience with the use of high-frequency ventilation as an alternative to conventional mechanical ventilation or as salvage therapy in patients failing conventional ventilation strategies.

## high-frequency positive-pressure ventilation

- High-frequency positive-pressure ventilation delivers small volumes (approximately 3 to 4 mL/kg) of conditioned gas at high frequencies (60 to 100 breaths/min) using a conventional mechanical ventilator.
- Valves in the inspiratory and expiratory limbs of the ventilator circuit allow control of the inspiratory flow rate (which is generally high) and positive end-expiratory pressure (PEEP), respectively.
- Expiration is passive and relies on the elastic recoil of the patient's respiratory system.

- The clinician controls the respiratory rate, inspiratory flow rate, diving pressure, and PEEP.
- Because high respiratory rates leave little time for passive expiration, there is a risk of gas trapping, with hyperinflation and resultant overdistention injury.

## high-frequency percussive ventilation.

- High-frequency percussive ventilation is a hybrid that attempts to combine the principles of high-frequency and conventional ventilation using a proprietary mechanical ventilator.
- A conventional ventilation circuit is fitted with a gas-driven piston at the end of the endotracheal tube. The reciprocating piston generates pressure oscillations at 3 to 15 Hz with short expiratory times, which are superimposed on the conventional inspiratory-expiratory pressure waves.

- The high-frequency beats are delivered in bursts to generate auto-PEEP through breath stacking, then stopped to allow alveolar pressure to fall back to baseline. It has been hypothesized that the auto-PEEP generated may improve alveolar recruitment without exposing the alveoli to the high peak airway pressures that would be generated with comparable conventional mechanical ventilation.

- Clinicians have control of all aspects of these underlying breaths, as well as the frequency and pressure of the high-frequency beats

## high-frequency jet ventilation.

- The clinician has control over frequency, inspiratory time, jet drive pressure, and mean airway pressure applied through the ventilator circuit. Larger tidal volumes can be delivered by increasing jet drive pressure and inspiratory time. Larger jet catheters and endotracheal tubes also augment tidal volume by increasing jet flow and gas entrainment, respectively. Because expiration is passive, gas trapping with intrinsic PEEP may occur at high frequencies when expiration is limited by progressively shorter expiratory times.

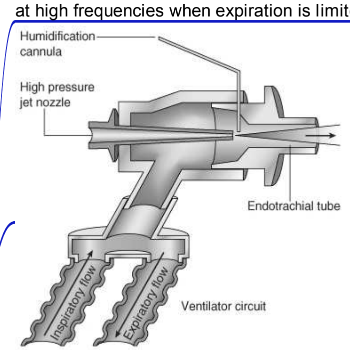




Figure 69-1 Typical high-pressure jet cannula and humidification system used in high-frequency jet ventilation. Note that the gas jet is directed down the endotracheal tube, entraining gas from the proximal ventilator circuit.

- Complications specific to high-frequency jet ventilation include:
(i) traumatic upper airway injury (necrotizing tracheobronchitis is a well-established complication of high-frequency jet ventilation in both infants and adults)
(ii) humidification and warming is problematic.
(iii) high gas flow rates and rapid increases in lung volume could cause lung injury through the generation of shear forces at the interface of adjacent compliant and atelectatic lung units.

## high-frequency oscillatory ventilation.

- In high-frequency oscillatory ventilation, an oscillating diaphragm creates pressure waves in the ventilator circuit.
- Because the diaphragm is actively driven in both directions, the ventilator creates both inspiratory and expiratory pressure waves, meaning that expiration is active. This distinguishes high-frequency oscillatory ventilation from other forms of high-frequency ventilation.

- Clinicians set the bias flow rate, mean airway pressure, frequency, inspiratory-expiratory ratio, and energy applied to the oscillating diaphragm.
- The generation of pressure oscillations is controlled in part by the frequency and the energy applied to the moving diaphragm (power).

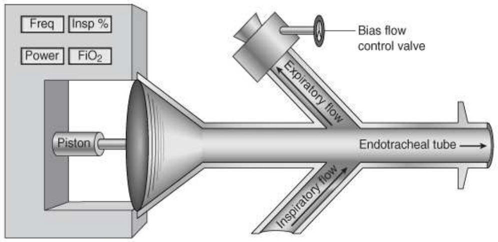




Figure 69-2 Schematic of high-frequency oscillatory ventilator. A computer allows precise control over the piston driving the oscillating diaphragm. Adjustment of the bias flow of conditioned gas allows control of mean airway pressure.

## mechanisms of gas transport

- During conventional mechanical ventilation, when tidal volumes are larger than anatomic deadspace, gas exchange is largely related to bulk flow of gas to the alveoli.
- High-frequency ventilation is thought to generate tidal volumes smaller than anatomic deadspace, and adequate ventilation under these conditions must rely on alternative gas exchange mechanisms.

- A number of proposed mechanisms may contribute to gas transport during high-frequency ventilation:
(i) When tidal volume approximates anatomic deadspace, the leading edge of the gas front may actually reach a number of proximal alveoli and thus contribute to some gas exchange through bulk flow.
(ii) Pendelluft is a phenomenon of regional gas movement that occurs as a result of heterogeneity in alveolar filling rates. The filling rate of a lung unit is dependent on its time constant (t), a property related to the product of compliance and resistance. Following inspiration, there is redistribution of inspired gas from full, fast-filling units to slower-filling units, augmenting gas exchange.
(iii) Convective streaming occurs as a result of the asymmetrical velocity profile of the inspired gas front as it moves through the bronchial tree. The asymmetry in gas velocity between the inspiratory and expiratory phases of breathing results in a net streaming of fresh gas down the inside walls of distal airways and of carbon dioxide ($CO_2$)-laden gas back along the outside walls.
(iv) In addition, the beating heart may enhance gas exchange through agitation of surrounding lung tissue (cardiogenic mixing) in these lung units and molecular diffusion.

## theoretical advantages

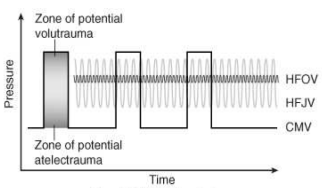




Figure 69-3 Comparative pressure-time diagram depicting the pressure-time swings for the most common modes of high-frequency ventilation compared with conventional mechanical ventilation (CMV). HFJV, high-frequency jet ventilation; HFOV, high-frequency oscillatory ventilation.

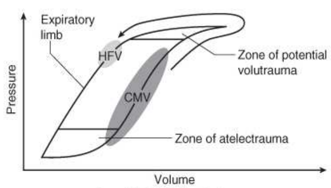




Figure 69-4 Pressure-volume curve depicting the "open lung" concept using high-frequency ventilation (HFV). Potential lung injury is reduced when ventilation of the lung is shifted onto the expiratory portion of the curve using aggressive lung recruitment. Lung volume is then maintained using high mean airway pressures and small tidal volumes. CMV, conventional mechanical ventilation.

- High-frequency ventilation may be well suited to accomplish all the goals of lung protection.
- By nature of its low tidal volumes, high-frequency ventilation may decrease the risk of overdistention injury.
- Because these tidal volumes are delivered using relatively small pressure swings at high rates, mean airway pressure can be maintained at higher levels than are generally used during conventional mechanical ventilation. This high mean airway pressure may optimize end-expiratory lung volume, leading to improved oxygenation and prevention of cyclic collapse and resultant atelectrauma.

## clinical experience

- High-frequency ventilation is largely considered an alternative mode of mechanical ventilation and traditionally has been used only in specialized situations or as salvage therapy when conventional mechanical ventilation fails.
- Although clinical experience with high-frequency ventilation in pediatric and neonatal populations is sizable, published experience with high-frequency ventilation modes in adults remains modest, with the largest experience involving high-frequency oscillatory ventilation and high-frequency jet ventilation.