High Frequency Jet Ventilation

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This Presentation Contains 71 Slides

Learning Objectives

- Explain the rationale, indications, & complications for high frequency jet ventilation (HFJV)
- Describe the equipment used in HFJV
- Explain patient management techniques associated with HFJV
- Apply jet ventilation management techniques in patient scenarios

High Frequency Ventilation

High Frequency Ventilation Types

- High frequency positive pressure ventilation - conventional ventilation with high frequencies
- High frequency flow interruption
  - Early form of HFV
  - Interruption of gas flow from a high pressure source at a high rate

High Frequency Ventilation Types

- High frequency percussive ventilation (HFPV)
  - High frequency pulsations with conventional breaths
  - Volumetric diffusive ventilation - Bird VDR 4™ applied to
    - Inhalation injuries - burn centers
    - Ventilation during airway surgery
    - Neonatal ventilation

High Frequency Ventilation Types

- High frequency oscillatory ventilation (HFOV)
  - High frequency ventilation with tidal volume less than dead space
  - First developed by Emerson - 1950s
  - Most common HFV technique for pediatric patients
  - Approved, available, & used for adults

High Frequency Ventilation Types

- High frequency jet ventilation (HFJV)
  - High frequency ventilation with delivery of a tidal volume (1-3 mL/kg) at a high flow (jet)
  - Originally used for short-term ventilation during airway surgery (1970s) because of capability to ventilate in face of leaks

Rationale, Principles, Indications, & Complications

Rationale

- Small tidal volume minimizes ventilator-induced lung injury & permits greater PEEP - lung protective ventilation strategy
- Short inspiratory time & small TV minimize flow through leaks

Mechanism for Gas Transport

- Bulk convection - jet of gas moves through the center of airways through dead space gas, delivering fresh gas to distal airways, with passive exhalation around the jet stream

Mechanism for Gas Transport

- Pendelluft - collateral exchange between distal units with varying compliance at
  - Airway bifurcations
  - Pores of Kohn
  - Canals of Lambert
- Simple molecular diffusion

See link below for illustration of gas exchange mechanisms

Mechanism for Gas Transport

- Resonant frequency - lungs have innate resonant frequency
- Ventilation is augmented because less pressure is required to ventilate lungs at their resonant frequency
  - 4 - 8 Hz (adults)
  - 10-12 Hz (small neonates)

Additional Effects

- Vibrations & expiratory flow along airway lumen mobilize secretions
- Short inspiratory time minimizes peak alveolar pressure - less pressure is transmitted to alveoli
- Small tidal volume minimizes lung motion during ventilation

Indications - Neonatal/Pediatric

- Ineffectiveness of other ventilation methods & BEFORE ventilator-induced lung injury occurs
- Evolving chronic neonatal lung disease (bronchopulmonary dysplasia)

Indications - Neonatal/Pediatric

- Failure of other ventilation methods & BEFORE ventilator-induced lung injury occurs
- Evolving chronic neonatal lung disease (bronchopulmonary dysplasia)
- Congenital diaphragmatic hernia
- Meconium aspiration
- Ventilation during transport, with or without inhaled nitric oxide

Indications - Neonatal/Pediatric

- Pulmonary air leaks
  - Pulmonary interstitial emphysema (PIE) - may speed resolution
  - Bronchopulmonary fistula
- Secretion mobilization, e.g. obstructive casts, meconium

Indications - All Patients

- Pulmonary air leaks, e.g. bronchopulmonary fistula
- Difficult airway management
  - Ventilation during intubation
  - Ventilation during tracheostomy
  - Ventilation during bronchoscopy

Indications - All Patients

- Pulmonary air leaks, e.g. bronchopulmonary fistula
- Difficult airway management
  - Ventilation during intubation
  - Ventilation during tracheostomy
  - Ventilation during bronchoscopy
- Elimination of lung motion during chest surgical procedures
- Ventilation during airway surgery
- Ventilation following pneumonectomy

Contraindication

- Effectiveness of conventional ventilation methods

Complications

- Intracranial hemorrhage
- Periventricular leukomalacia - ischemic white matter injury
- Hypotension
- Air trapping - inadvertent PEEP
- Pneumo/thorax/mediastinum
- Mucosal desiccation - inadequate humidification

Evidence on Effectiveness

- Meta-analyses of RCTs on HFJV for premature infants conclude that there is inadequate evidence - not enough trials
- HFJV is another tool that requires judicious application on a case-by-case basis

Jet Ventilators

Jet Ventilation Techniques

- Normal frequency jet ventilation
- High frequency jet ventilation – rates >60/min
- Combined frequency jet ventilation – rates > 60/min combined with normal rates

Jet Ventilators

- No longer manufactured
  - Infrasonic Adult Star™
  - Bear 150™
- Bunnell Life Pulse™
- Accutronics
  - Mistral™
  - Monsoon™

Bunnell Life Pulse™

- Currently used for neonates & pediatric patients (≤ 28 kg) in USA
- Applied in tandem with companion ventilator that provides
  - PEEP
  - Sigh breaths
  - Spontaneous breathing source gas

Bunnell Life Pulse™

- Controls - companion ventilator
  - FiO_2 - ideally, same blender as jet
  - Rate ≤ 5/min - ideally zero
  - PEEP - adjusts mean airway pressure (MAP)
  - Peak inspiratory pressure (PIP)

Bunnell Life Pulse™

- Controls - jet
  - FiO_2 - low-flow blender, ideally same blender as companion
  - Peak inspiratory pressure (8 - 50 cm H_2O)
  - Rate (240 - 660/min)
  - On time (inspiratory time) - (0.02 -0.034 sec)

See link below to view Life Pulse panel (click individual sections)

Bunnell Life Pulse™

- Monitors
  - Jet PIP displays distal pressure (companion PIP displays proximal pressure)
  - PEEP
  - Δp (PIP - PEEP)
  - Mean airway pressure
  - Servo pressure - servo-controlled drive pressure that adjusts flow to maintain PIP

Accutronics Mistral™

- Short-term ventilation, e.g. operating room
- Controls
  - Rate 12-150/min
  - Inspiratory time% 20-60%
  - Drive pressure 5 - 40 psi

Accutronics Monsoon™

- Short or long-term (includes humidification)
- Controls
  - Rate 12-1,600/min
  - Inspiratory time% 20-60%
  - Drive pressure 5 - 40 psi
  - Humidification - up to 100% RH

See link below to view Accutronics Monsoon™ ventilator

Accutronics Monsoon™

- Additional features
  - Color touch screen
  - Detachable control panel
  - Options
    - Video camera
    - $EtCO_2$
    - $TcCO_2$
    - Double jet

HFJV Airway Devices

Airway Devices

- Bunnell LifePortTM adapter - for Life Pulse™ ventilator
  - Attaches to ETT & pressure monitoring port
  - Approximates distal airway pressure
  - Use the same size as ETT or larger

See link below to view Bunnell LifePort™ adapter (click LifePort)

Airway Devices

- Triple-lumen jet endotracheal tube
  - Ports
    - Distal pressure monitoring
    - Companion ventilator
    - Jet ventilator

Airway Devices

- Percutaneous catheter
  - Ventilation via cricothyrotomy
  - Difficult airway management strategy

See link below to view percutaneous catheter
FYI see link below for article on percutaneous jet ventilation

Airway Devices

- Endotracheal jet catheter
  - Translaryngeal ventilation
  - Microlaryngeal surgical procedures

See link below to view intubation with Hunsaker Mon-jet™ tube (1.2)

Airway Devices

- Univent™ tube - bronchial blocking tube intended for single lung ventilation

HFJV Patient Management

Airway Management

- Suctioning - needed more frequently during initial hours on jet ventilation

Initiation

- Patient already on conventional or oscillatory ventilation
- Follow Bunnell startup procedure, including attachment of LifePort adapter

FYI see link below to bookmark Bunnell Life Pulse™ slides

Ventilator Control Adjustment

- Companion controls
  - FiO_2 - both ventilators
  - PIP or TV, as previously adjusted
  - Rate
    - Weaned to zero, as tolerated
    - Desaturation during weaning indicates need for greater MAP
  - PEEP - adjust to maintain MAP
  - Oxygenation maintained with
    - FiO_2
    - MAP

Ventilator Control Adjustment

- Jet controls
  - On time
  - Rate
  - PIP - adjusts TV (Δp)

Jet Control Adjustment

- On time
  - Defaults to 0.02 sec
  - Usually left on default setting
  - At lowest rate (240) I:E = 1:12

Jet Control Adjustment

- Rate (240-660) - not the primary control for PaCO2
  - Typical jet rate ≥ 10 times CMV rate
  - For small infants, start at 420/min
  - Lower rates for
    - Larger infants
    - PIE
    - Meconium aspiration
    - Gas trapping, reversal of which may decrease $PaCO_2$

Jet Control Adjustment

- PIP - control over $PaCO_2$
  - Adjusts TV (Δp)
  - With HFV, VE = f x TV^2 → smaller TV changes have greater effect
  - Start with PIP 1-2 cm less than CMV PIP
  - Adjust for desired $PaCO_2$
  - Transcutaneous CO_2 monitor is helpful in adjusting PIP

Ventilation Monitoring

- Servo pressure
  - Fluctuates like PIP with patient activity & position
  - Should change in direction of PIP setting

Ventilation Monitoring

- Servo pressure
  - Decreased by
    - Decreased compliance
    - Increased resistance
    - Obstructed ETT
  - Increased by
    - Increased compliance
    - Decreased resistance
    - Leak in system
  - Increased servo P is usually good, but may indicate leak

Ventilation Monitoring

- Proximal-distal pressure difference
  - Jet PEEP display is measured distally
  - CMV PEEP display is measured proximally
  - Significant difference between distal & proximal indicates intrinsic PEEP (PEEPi)
  - Decrease rate to eliminate PEEPi

Discontinuation

- Condition that precipitated need for HFJV must be resolved before weaning
- Wean slowly
- Maintain MAP for oxygenation

Discontinuation

- Decrease PIP slowly (1-2 cm H_2O)
- Decrease PEEP, which controls the MAP, to 8 or less as consistent with adequate oxygenation
- Decrease FiO_2 to 30%
- Change to CPAP or nCPAP when PIP < 15 cm H_2O & CMV rate at or near CPAP

Case Scenarios

Case One

- 26 wk 700 g BG
- Intubation & surfactant in DR
- Initial ventilator settings TV = 12 mL, rate = 60/min, FIO_2 = 60%, PEEP = 6 cm H2O - couldn't wean FIO_2
- More surfactant - no changes (RDS)
- Over 36 H, PIP increased from low 30s to 55 cm H_2O - see CXR after CMV

See links below to view CXR before CMV & CXR after 36 H on CMV

Case One

- Diagnosis - PIE
- Conventional ventilator: FiO_2 = 60%, MAP = 22 cm H_2O, PIP = 55 cm H_2O
- Initial settings for jet ventilation
  - Companion: FiO_2 = 60%, PEEP = 12 (for MAP = 22), rate = 5/min
  - Jet: FiO_2 = 60%, PIP = 50 cm H_2O, rate = 420/min, On time = .020
- ABGs: PaO_2 = 60 mm Hg, SaO_2 = 93%, $PaCO_2$ = 35 mm Hg, pH = 7.42

Case One

- ABGs: PaO_2 = 60, SaO_2 = 93%, $PaCO_2$ = 35, pH = 7.42
- Ventilator adjustments
  - Companion rate to zero - SPO_2 decreased, increased MAP to 23 cm H_2O with SPO_2 rebound
  - Decreased PIP to 47 cm H_2O, PCO_2 increased to 36 mm Hg
- Over 24 H, FiO_2 decreased to 42% & PIP decreased to 40 cm H_2O
- PIE resolving on radiograph

Case One

- At 48 H on jet, ABGs: PaO_2 = 70, SaO_2 = 95%, $PaCO_2$ = 32, pH = 7.46
- FiO_2 weaned to 30%
- PIP weaned to 10 cm H_2O
- PEEP weaned to 8 cm H_2O
- Patient stable on CPAP 8 cm H_2O, FiO_2 = 30%
- Extubated to nCPAP

Case Two

- 41 wk, 3,500 g BB
- Delivered with meconium in amnion & in upper airways
- Intubated, suctioned through ETT
- Lavaged with surfactant
- Placed on nCPAP = 6, FiO_2 = 35%, SpO_2 = 89%, then to NICU
- 6 H later, SpO_2 decreased & RR increased to 80/min

See link below to view a radiograph of MAS

Case Two

- Placed on volume-control ventilator with FiO_2 = 50%, TV = 22 mL, rate = 40/min, PEEP = 6 cm H_2O, PIP = 48 cm H_2O, MAP = 18 cm H_2O
- ABGs: PaO_2 = 45 mm Hg, SaO_2 = 81%, PCO_2 = 76 mm Hg, pH = 7.18
- Changed to jet ventilator
- Settings??

Case Two

- Initial settings for jet ventilation
  - Companion FiO_2 = 60%, PEEP = 8 cm H_2O for MAP = 18 cm H_2O, rate = 5/min
  - Jet FiO_2 = 60%, rate = 360/min, PIP = 46 cm H_2O
- ABGs: PaO_2 = 42 mm Hg, $PaCO_2$ = 75 mm Hg, pH = 7.10

Case Two

- Ventilator adjustments
  - Companion PEEP increased to 10 cm H_2O for MAP = 20 cm H_2O, rate decreased to zero
  - Jet rate decreased to 240/min
- ABGs: PaO_2 = 59 mm Hg, SaO_2 = 91%, $PaCO_2$ = 55 mm Hg, pH = 7.27
- CXR - less hyperinflation
- Note: increased PIP might decrease $PaCO_2$, but decreased rate worked by decreasing I:E

Case Two

- Over two days, CXR improved & patient stable on FiO_2 = 38%, PIP = 22 cm H_2O, PEEP = 8 cm H_2O
- PIP weaned to zero, FiO_2 weaned to 30% with patient stable
- Patient extubated to nCPAP

Summary & Review

- HFV types
- HFJV definition & types
- HFJV rationale
- Mechanisms for gas transport
- HFJV indications
- HFJV complications

Summary & Review

- Jet ventilators
  - Bunnell LifePulse™
  - Accutronics
    - Mistral™ - short-term only
    - Monsoon™
- Bunnell controls
  - Rate
  - PIP
  - On time

Summary & Review

- Jet airway devices
  - Bunnell LifePort™
  - Triple-lumen jet endotracheal tube
  - Cricothyrotomy catheter
  - Translaryngeal catheter

Summary & Review

- HFJV management
  - Control adjustments
    - Oxygenation - MAP, FiO_2
    - $PaCO_2$ - PIP (Δp)
    - Rate - decreased for air-trapping
  - Monitoring
    - Servo P
    - Distal - proximal pressure difference
  - Discontinuation

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