High-Frequency Oscillatory Ventilation

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Learning Objectives

- Describe the indications and rationale and monitoring for HFOV.
- Identify HFOV settings and describe the effects of their adjustment.
- Discuss case presentations involving HFOV.

Definition and Description

- Definition- rapid rate ventilation with small tidal volume (often less than dead space).
- Goal- oxygenate and ventilate without ventilator-induced lung injury.

Definition and Description

- HFOV- AKA (also known as) CPAP with a wiggle.
  - CPAP- sustained lung inflation for alveolar recruitment
  - Wiggle- alveolar ventilation with oscillating pressure waveform at adjustable frequency (Hz) and amplitude (delta P)

Rationale

- HFOV effectively ventilates with intrapulmonary pressure and volume changes that are less than conventional ventilation.
  - decreased volutrauma
  - decreased barotrauma

Indications

- Failure of conventional mechanical ventilation (CMV) and before ventilator-induced lung injury (VILI) occurs
- Some studies favor HFOV before frank failure of CMV

Indications

- ARDS/ALI (adults)
- Air leaks:
  - pneumothorax
  - PIE (pulmonary interstitial emphysema).

Indications

- Other neonatal indications
  - RDS
  - meconium aspiration
  - persistent pulmonary hypertension
  - pulmonary hemorrhage
  - pulmonary hypoplasia
  - congenital diaphragmatic hernia

Complications

- Hypotension
  - due to decreased venous return
  - responds to fluid bolus

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  - sudden onset of hypotension
  - decreased chest wiggle

Complications

- Hypotension
  - due to decreased venous return
  - responds to fluid bolus
- Pneumothorax
  - sudden onset of hypotension, desaturation
  - decreased chest wiggle
- ETT obstruction
  - hypercapnia, desaturation
  - decreased chest wiggle

Relative contraindications

- increased ICP
- obstructive lung disease

HFOV Ventilators (US)

- SensorMedics
  - 3100a- neonates and small children
  - 3100b - large children (> 35 kg) and adults

SensorMedics 3100a
Courtesy of Cardinal Health

Link to Cardinal Health Powerpoint Lessons
http://www.viasyshealthcare.com/prod_serv/prodref.aspx?config=ps_prodref

HFOV Ventilators (US)

- Drager Babylog

Image used with permission from Drager Medical

Link to Drager Medical
http://www.draeger.com/MTms/internet/site/MS/internet/USA/ms/index.jsp

HFOV Ventilators (US)

- Infant Star 950

Monitoring

- Arterial line
  - blood pressure
  - blood gas analysis
- SPO2
- Endotracheal tube leak

Monitoring

- Chest Wiggle factor (CWF)
  - absent or diminished- airway obstruction
  - asymmetric- endobronchial intubation
  - check, especially after patient repositioning

Monitoring

- Chest radiograph
  - Initially- should be frequent
  - 8.5-9.0 ribs should be visible- infants and adults
  - monitor for expansion, hyperexpansion

Ventilator Settings

- Mean airway pressure (MAP)
  - In conjunction with FIO2, used to adjust oxygenation
  - Initial settings
    - 2-5 cm H2O greater than MAP for CMV (high volume strategy)
    - 2 cm H2O less than CMV for air leak syndromes (low volume strategy)

Ventilator Settings

- Mean airway pressure (MAP)
  - Adjusted in 1-2 cm H2O increments, as determined by:
    - CXR
    - Oxygenation- PaO2, SPO2
    - FiO2- MAP used to reduce FiO2

Ventilator Settings

- Amplitude (delta P)
  - SensorMedics- power control adjusts the piston displacement
  - Adjusted for chest wiggle factor (CWF)
    - neonates from nipple line to umbilicus
    - adults from clavicles to mid-thigh.

Ventilator Settings

- Amplitude (delta P)
  - Initially set at:
    - neonates- 2 cm H2O
    - adults 6-7 cm H2O
  - Changed in 1-2 cm increments
  - Similar to TV adjustment
  - For HFOV, VE = $f \times TV^2$

Ventilator Settings

- Amplitude (delta P)
  - Increased delta P ==> decreased PaCO2- used to change PaCO2
  - When amplitude changed, MAP requires change

Ventilator Settings

- Frequency- Measured in Hertz (Hz)
  - 1 Hz = 1/sec
  - 1 Hz = 60/min
- Changing frequency also changes delta P and MAP
- Increased frequency ==> increased PaCO2
- Initial frequency settings
  - adults 5-6 Hz

Ventilator Settings

- Initial pediatric frequency settings

1000 g	15 Hz
1000-2000 g	12 Hz
2.0-10.0 kg	10 Hz
13-20 kg	8 Hz
21-30 kg	7 Hz
>30 kg	6 Hz
Meconium aspiration	3-6 Hz

Ventilator Settings

- TI%- proportion of cycle occupied by inspiration
  - initial setting = 33%
  - increased TI% ==> increased TV ==> affects PCO2
  - increased TI% decreases PCO2

Ventilator Settings

- Bias flow
  - generates pressure in circuit
  - flushes CO2
  - Initial settings (usually not changed)
    - 10-15 L/min term neonate
    - 25-40 L/min (adults)

Ventilator Settings

- Bias flow
  - too low- MAP not attained
  - too high- dampens exhalation, increasing PCO2

Strategies for increased PCO2

- Permissive hypercapnea
- Deflate tube cuff (adults)
  - permits CO2 excretion
  - must adjust MAP to compensate for loss

Weaning, transition to CMV

- Criteria
  - resolution of pathology
  - clinical stability
  - tolerance of procedures
- wean FiO2 <50%

Weaning, transition to CMV

- slowly- decrease MAP in 1 cm H2O decrements
- when MAP <25, consider:
  - CMV with optimal TV
  - PCV with optimal TV
  - APRV
  - SIMV (Infant Star)

Precautionary notes

- Competency-based training required for all personnel before they use HFOV
- Patients will require sedation, paralysis
- Ventilator is not transportable

Precautionary notes

- Pneumatic nebulizer may not be used with HFOV
- Limit disconnects, suctioning, bronchoscopies
- Consider recruitment maneuvers after disconnects, suctioning.

Case Examples

Case One

- 27 wk GA 1095g BB delivered to 32 YO G2P1 mom. Initial pH = 6.90.

Apgars = 6;4

- BB intubated and hand-bagged. ABG: 7.38/37/111
- BB placed on ventilator @ f = 40; PIP = 26; FIO2 = 1.0; PEEP = 5.
- 4.3 ml Survanta given via ETT adapter. ABG: 7.43/37/58

Case One

- BB worsened over next 4 H; vent settings advanced to: f = 60; PIP = 36; FIO2 = 1.0; PEEP = 5. (MAP = 22)

ABG: 7.22/54/46.

Case One

- BB placed on HFO, settings: f = 12 Hz; MAP = 24; delta P = 42.
- ABG: 7.28/62/174. CXR shows hyperinflation (10th rib) with flattened diaphragms.
- What to do about PCO2?
- What to do about hyperinflation?

Case One

- What to do about PCO2?
  - leave it; the pH = 7.28 or
  - increase delta P or decrease frequency
- What to do about hyperinflation?
  - MAP weaned to 22 cm, monitoring SpO2 and CXR.
- ABG: 7.34/48/125.

Case One

- over 2 D, FIO2 weaned to 40%, maintaining SpO2 > 94%. MAP weaned to 15; delta P weaned to 20.
- BB changed to PCV 25/5 (MAP = 14 cm H2O); f = 30/min; FIO2 = 40%.
- ABG: 7.47/34/96.
- Conventional settings successfully weaned over next two days and BB extubated without sequelae.

Case Two

- BG is 39 wk, 3400 g infant vaginally delivered to 27 YO G1P0 mom with complete prenatal care.
- At delivery, amniotic fluid is meconium stained and BG is distressed.

Case Two

- Direct laryngoscopy reveals thick meconium in airways.
- BG intubated with 3.5 mm ETT and suctioned with meconium aspirator for thick meconium.

Case Two

- BG lavaged with Survanta and placed on SIMV: f = 40; PIP = 25; PEEP = 5;
- FIO2 = 1.0
- ABG: 7.21/78/73
- Over several hours, f increased to 60; PIP increased to 40.

Case Two

- BG worsened. CXR revealed Rt pneumothorax. Post-chest tube ABG: 7.08/85/46.
- HFO initiated. f = 5 Hz; delta P = 32; MAP = 26.
- ABG: 7.19/75/45
- What to do about PaO2?
- What to do about PaCO2?

Case Two

- ABG: 7.19/75/45
- What to do about PaO2?
  - MAP increased to 30, observing SPO2 and CXR
- What to do about PaCO2?
  - delta P increased to 36
- ABG: 7.32/52/85

Case Two

- Over two days, BG improves; but small air leak persists.
- FIO2 weaned to 40% with SPO2
- ABG: 7.56/24/213
- Next changes?

Case Two

- Over two days, BG improves; but small air leak persists.
- FIO2 weaned to 40% with SPO2
- ABG: 7.56/24/213
- Next changes?
  - reduce MAP, using SpO2 = 94%
  - reduce delta P to 30 for PaCO2

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