High Frequency Ventilation (HFV-1.PPT)

High Frequency Ventilation

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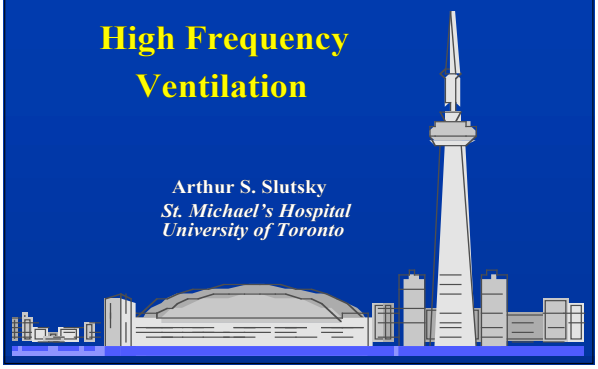


Conflict of Interest Disclosure

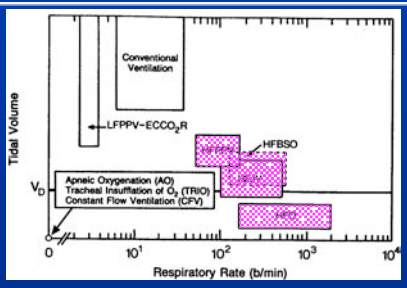
- Asthmatx: Chair, DSMB
- BOC: Advisory Board
- Broncus: Chair, DSMB
- GSK (Canada): Chair, Asthma Advisory Board
- Hamilton: Consultant
- KCI: Advisory Board
- Leo Pharma: Chair, DSMB
- Maquet: Consultant
- Sensormedics

Overview

- What is HFV?
- Pathophysiology of ARDS
- HFV: ventilator-induced lung injury
- Important messages:
  - »recruitment
  - »high mean airway pressure
  - »early intervention
- Conclusions

High Frequency Ventilation (HFV-1.PPT)

What is High Frequency Ventilation?



Slutsky AS *Amer Rev Respir Dis* 1988: 138;175-183

High Frequency Positive Pressure Ventilation (HFPPV)

- Sjostrand and colleagues (1967)
  - »physiological tool
- Characteristics
  - »$60 < f < 120$ /min
  - »$V_t > V_d$
  - »Passive exhalation
- Clinical uses
  - »bronchoscopy, ARDS

High Frequency Jet Ventilation (HFJV)

- Compressed gas via small-bore catheter
- Characteristics
  - »$60 < f < 400$ /min
  - »$V_t > V_d$
  - »gas entrainment
  - »Passive exhalation
- Clinical uses
  - »ARDS, B/P Fistula, routine ventilation

High Frequency Ventilation (HFV-1.PPT)

High Frequency Oscillations (HFO)

- Lunkenheimer (1972)
- Characteristics:
  - » active inspiration and exhalation
  - » 120 < f < 1200 /min
  - » $V_t < V_d$
  - » bias flow
- Clinical uses
  - » Neonatal Respiratory Distress Syndrome, Acute Lung Injury (ALI)

FDA Approved High Frequency Ventilators for Adults

SensorMedics 3100B

Volume Diffuse Respirator (VDR)

High Frequency Ventilation: Potential Benefits

Effects due to high frequencies

- » at low frequencies, distribution of ventilation determined by regional parenchymal properties (compliances)
- » at high frequencies, distribution of ventilation depends on airway properties (inertance)

- Decreased lung movement
  - » surgical procedures
  - » decreased lung injury

High Frequency Ventilation (HFV-1.PPT)

High Frequency Ventilation: Potential Benefits

- Effects due to small tidal volumes:
  - »decreased intrathoracic pressures
    - –decreased intracranial pressures
    - –improved hemodynamics
    - –decreased VILI

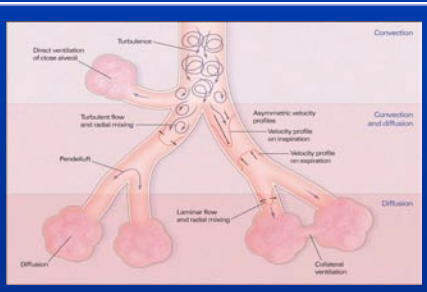
Detrimental Effects of HFV

- $V_A \sim V_t f^2$: flows are much higher than CMV
  - »humidification of gases
  - »necrotizing tracheobronchitis
  - »auto-PEEP, especially in patients with airways obstruction
- Lack of familiarity with HFV
- Monitoring of patients
  - »physical exam

HFV – how does it work?

High Frequency Ventilation (HFV-1.PPT)

High-Frequency Ventilation: Gas Transport Mechanisms



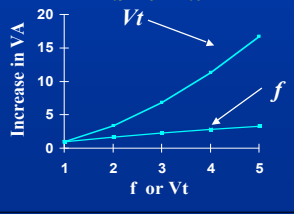
Slutsky & Drazen N Engl J Med *2002;347:630-631*

Alveolar ventilation during HFV

Alveolar ventilation = K $f^a Vt^b$

$0.5 < a < 1.0$

$1.5 < b < 2.0$



High Frequency Ventilation: Strategies

- **Ventilation**
- **Oxygenation**
- **Lung injury**

High Frequency Ventilation (HFV-1.PPT)

HFV Strategies: Ventilation

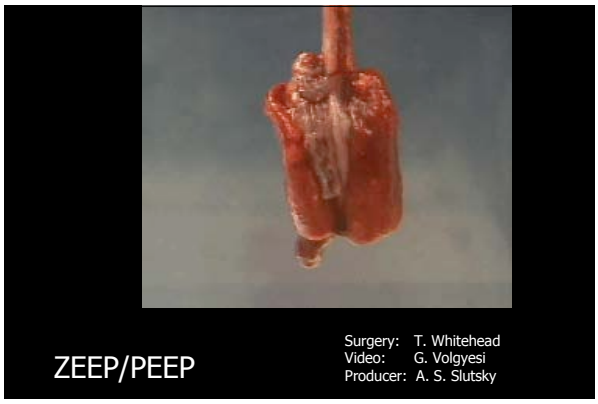
- V_t depends on a number of factors (HFPPV, HFJV)
  - » V_t ↓ as f ↑
  - » V_t dependent on ET tube diameter, compliance
- Strategies different during HFV compared to CMV
  - » $V_A \sim V_t f^2$;
- If $PaCO_2$ is ↑ :
  - » ensure patent ET tube
  - » ↑ driving pressure; ↑ Inspiratory time
  - » depending on ventilator and settings: ↓ f or ↑ f
  - » Deflate ETT cuff

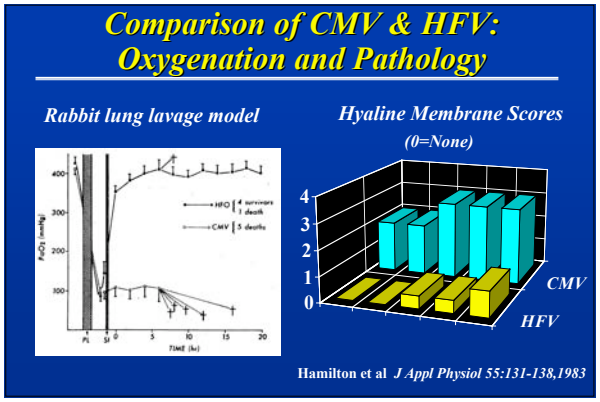
HFV Strategies: Oxygenation

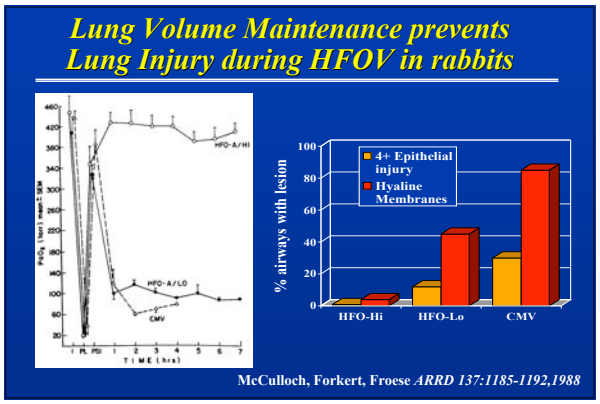
- Basic concepts similar to CMV
  - » use F_IO_2 the same way as during CMV
  - » PaO_2 ↑ with lung recruitment
- *The Challenge*: recruit lung volume as much as possible without affecting hemodynamics
  - » CMV: ↑ lung volume -PEEP, ↑ T_i, ↑ V_t (or pressure), ↑ f
    - – (Paw measured but not directly manipulated)
  - » HFV: ↑ lung volume - ↑ Paw, driving pressure, ↑ I:E

VILI and High Frequency Ventilation

High Frequency Ventilation (HFV-1.PPT)



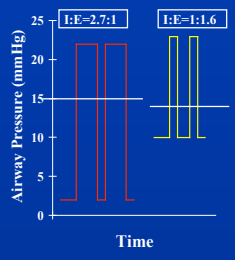




High Frequency Ventilation (HFV-1.PPT)

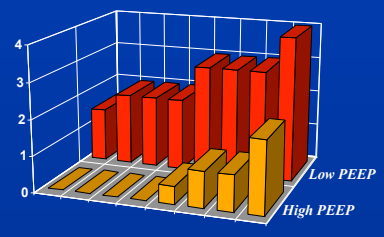
Effects of PEEP on Hyaline Membrane Formation in a rabbit model of neonatal RDS

- ***Purpose:*** **To examine whether using PEEP above the inflection point reduces lung injury**
- ***Methods:*** **lavaged rabbits**
  - » **ventilated with CMV**
  - » **peak Paw, mean Paw, FIO_2=1.0 was constant in both groups**



Sandhar et al *Intens Care Med 14:538-546,1988*

Effect of PEEP on Hyaline Membranes in Rabbits



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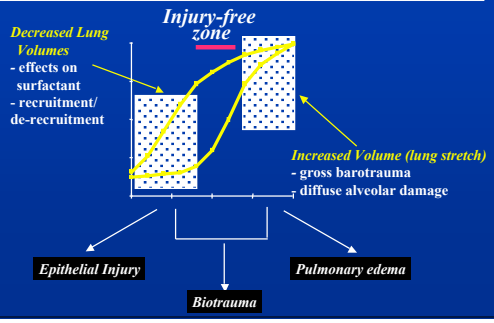
Ventilatory Strategy during HFV



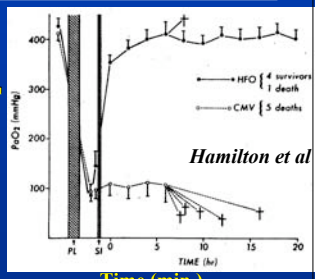
High Frequency Ventilation (HFV-1.PPT)

Timing of HFV Intervention is Critical

Timing of HFO and a Recruitment Maneuver may be Important for HFO Success

- Saline Lavaged Rabbits
- 4 hours of conventional ventilation followed by HFO with and without Sustained Inflation (30 cm H_2O for 10 sec)

PaO_2



Time (min.)

Suzuki et al. Acta Paediatr Jpn 1991;498

Clinical Studies

High Frequency Ventilation (HFV-1.PPT)

HFV for ARDS: A Pilot Study

- ***Purpose:*** **To evaluate safety & effectiveness of HFOV using a recruitment protocol in patients with ARDS**
- ***Methods:*** **Prospective study in 17 pts with severe ARDS (LIS: 3.81±0.23; P/F: 68.6 ± 21.6; PEEP: 18.2 ± 6.9)**
  - **lung recruitment strategy: increases in Paw to achieve $PaO_2 \geq 60$ with $FiO_2 \leq 0.6$**
- ***Results:*** **13 pts - improved OI; no significant hemodynamic consequences; survival=47%**
- ***Conclusions:*** **HFOV safe & effective in adults with severe ARDS; recruitment helpful; need RCT comparing HFV *vs* CV**

Fort P, et al. *Crit Care Med* 1997;25:937-47

HFV for ARDS: A Pilot Study

Early Intervention May Be Important

8/17 Survived	**HFO started mean of 2.5 days after CMV**
9/17 Died	**HFO started mean of 7.2 days after CMV**

Fort P, et al. *Crit Care Med* 1997;25:937-47

Multicenter Oscillatory ARDS RCT

Derdak et el* AJRCCM *166:801-808,2002

- **Comparison of HFOV and a Pressure Control Ventilation approach in severe ARDS (>16 yrs old) in 10 University based centers**
- **Open lung strategies in both arms**
- **Limited pressures and permissive hypercapnia in both arms**

High Frequency Ventilation (HFV-1.PPT)

High Frequency Oscillatory Ventilation in ARDS

Derdak et al AJRCCM 2002;166:801

	CV(PCV)	HFO
VT ml/kg ABW	6-10	------
RR	35/min	5 (3-8) Hz
PEEP cmH_2O	10-18	-------
mPaw cmH_2O	------	CV+5 (max 45)
Delta P cmH_2O	------	CW vibration
% Inspir time	33-66%	33%

HFO used cuff leak to improve ventilation

HFO to CV when mPaw < 24cm H2O, FIO_2 < 0.5

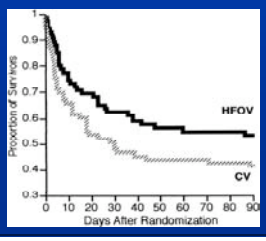
Multi-center Oscillator ARDS Trial (MOATII)

	HFOV	CMV
N	75	73
Age	48	51
P/F	114	111
APACHE II	22	22
ARDS Trigger		
Sepsis	47%	47%
Pulm	19%	16%
Trauma	21%	18%
Other	13%	19%

Results

Derdak et el *AJRCCM* 166:801-808,2002

- No significant differences in:
  - » hemodynamics, oxygenation failure, ventilation failure, barotrauma, mucus plugging



High Frequency Ventilation (HFV-1.PPT)

Can the same decrease in injury be obtained using CMV and an appropriate lung protection strategy?

Comparison of lung protection strategies using conventional and HFO ventilation

- ***Hypothesis:***
  - » **HFV would afford better protection against VILI than lung protection approaches using conventional ventilation**
- ***Key Issue:***
  - » **how to chose optimum conventional ventilatory strategies**
- ***Rationale for study design:***
  - » **use strategies that have been shown to be effective in other studies**

Imai, Nakagawa, Ito, Kawano, Slutsky, Miyasaka

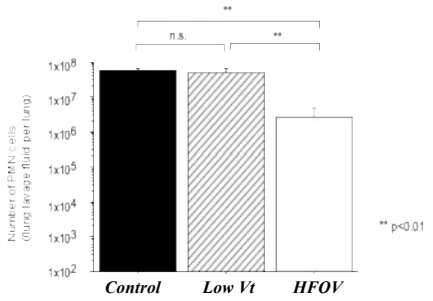
Comparison of lung protection strategies using conventional and HFO ventilation

- ***Methods:***
  - » **rabbit lung lavage model**
  - » **4 groups: CONTROL: PEEP 5 cmH_2O; Vt 12 ml/kg; MAP 15**
    - ***Protective strategies:***
    - **(1) PEEP > Pinf; Vt=5-6 ml/kg (AMATO-like)**
    - **(2) PEEP 10 cmH_2O: Vt 5-6 ml/kg; MAP 15 (NIH-like)**
    - **(3) HFV MAP 15 cmH_2O; f 15 Hz**
  - » **all groups ventilated for 4 hours**
- ***Results:*** **group 1: severe hypotension; pneumothoraces; therefore, not studied further**

Imai, Nakagawa, Ito, Kawano, Slutsky, Miyasaka JAP 2001;91:1836-1844

High Frequency Ventilation (HFV-1.PPT)

Lavage Neutrophils



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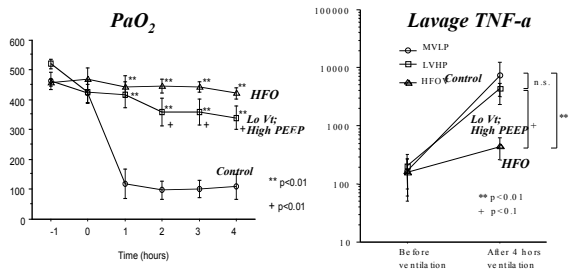
Oxygenation and TNF-α



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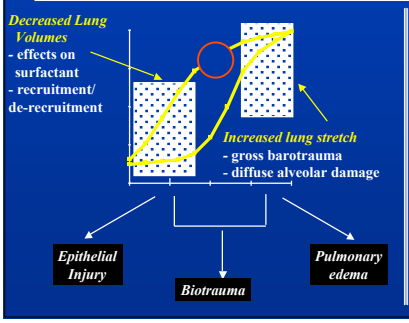
Summary



Key Messages

- Recruitment
- High mean airway pressure
- Early intervention
- Possibly better than lo-Vt CMV