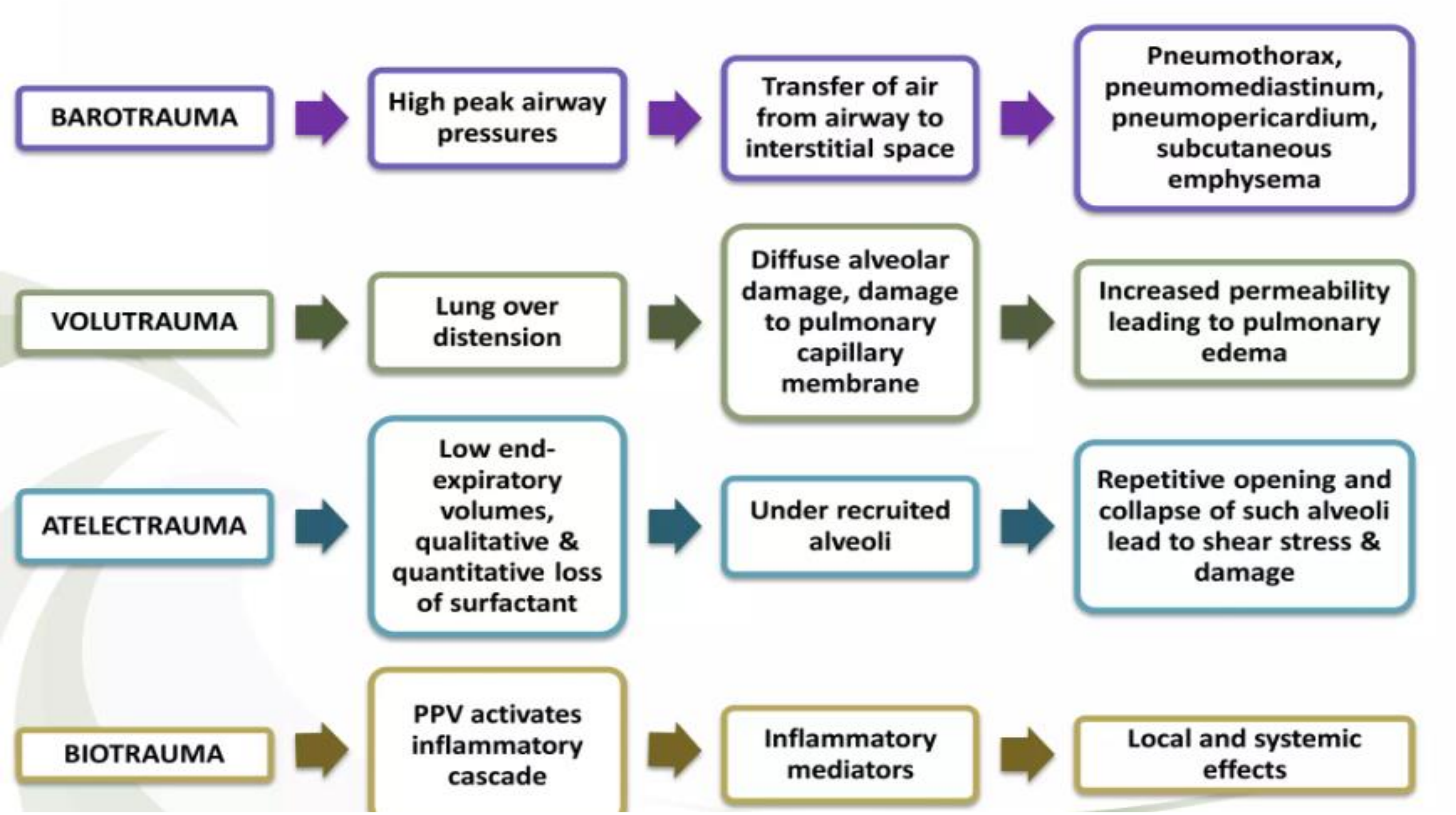
High Frequency Ventilation

VILI


BAROTRAUMA
High peak airway pressures
Transfer of air from airway to interstitial space
Pneumothorax, pneumomediastinum, pneumopericardium, subcutaneous emphysema
VOLUTRAUMA
Lung over distension
Diffuse alveolar damage, damage to pulmonary capillary membrane
Increased permeability leading to pulmonary edema
ATELECTRAUMA
Low end-expiratory volumes, qualitative & quantitative loss of surfactant
Under recruited alveoli
Repetitive opening and collapse of such alveoli lead to shear stress & damage
BIOTRAUMA
PPV activates inflammatory cascade
Inflammatory mediators
Local and systemic effects

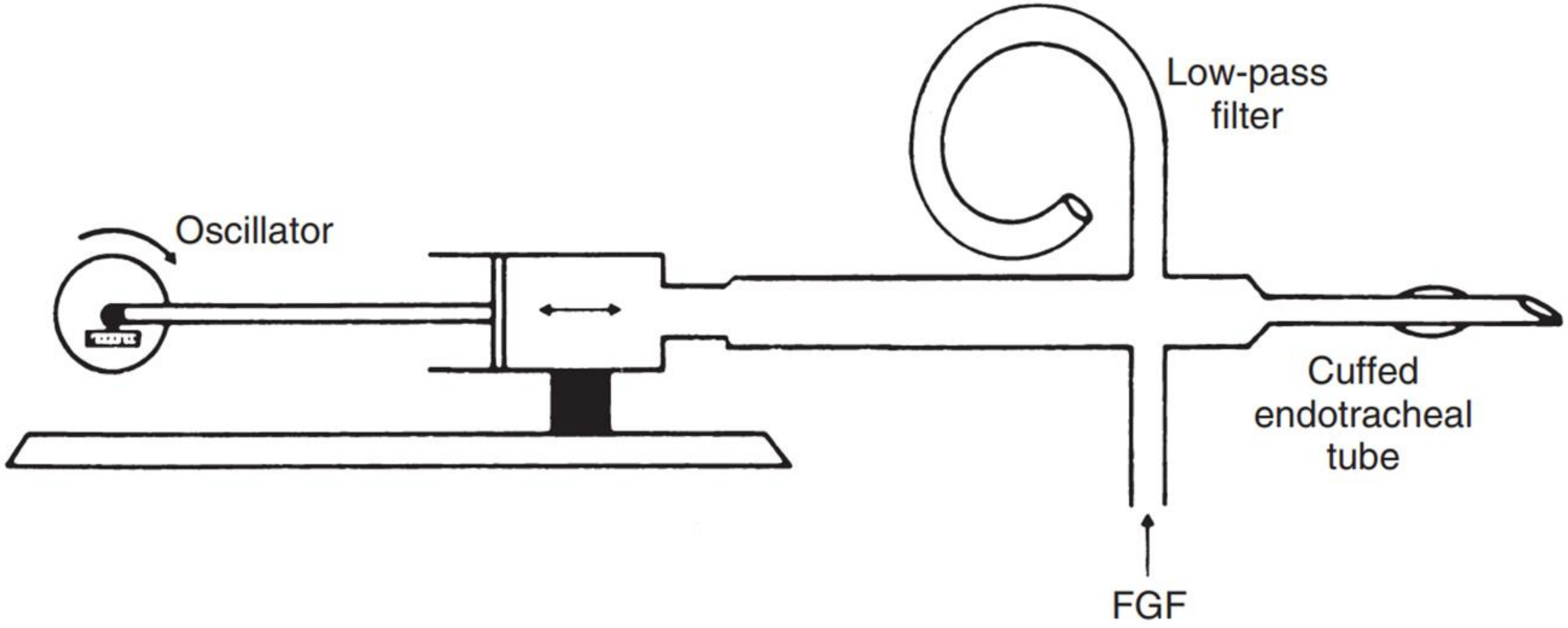
HFOV

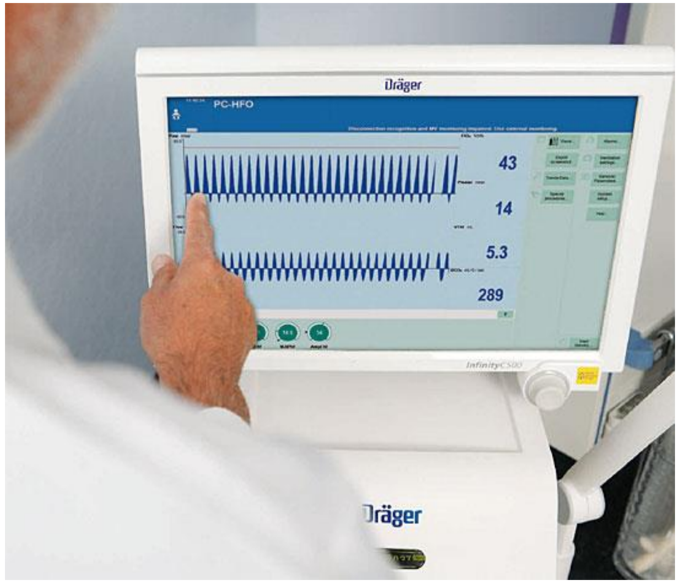
- Lung protective strategy
- Small TV ≤ anatomical dead space
- At supraphysiologic frequencies (150-1200 cycles per minute – 2.5 to 20 Hz, 1Hz – 1 cycle/sec)

HIGH FREQUENCY OSCILLATORY VENTILATION

- Piston pumps or vibrating diaphragms operating at a frequency of 150-1200 cycles per minute to vibrate air in and out of the lung.
- Tidal volume 1-3 ml/kg
- Both inspiration and expiration are active
- Oxygenation and ventilation are decoupled

HIGH FREQUENCY OSCILLATOR



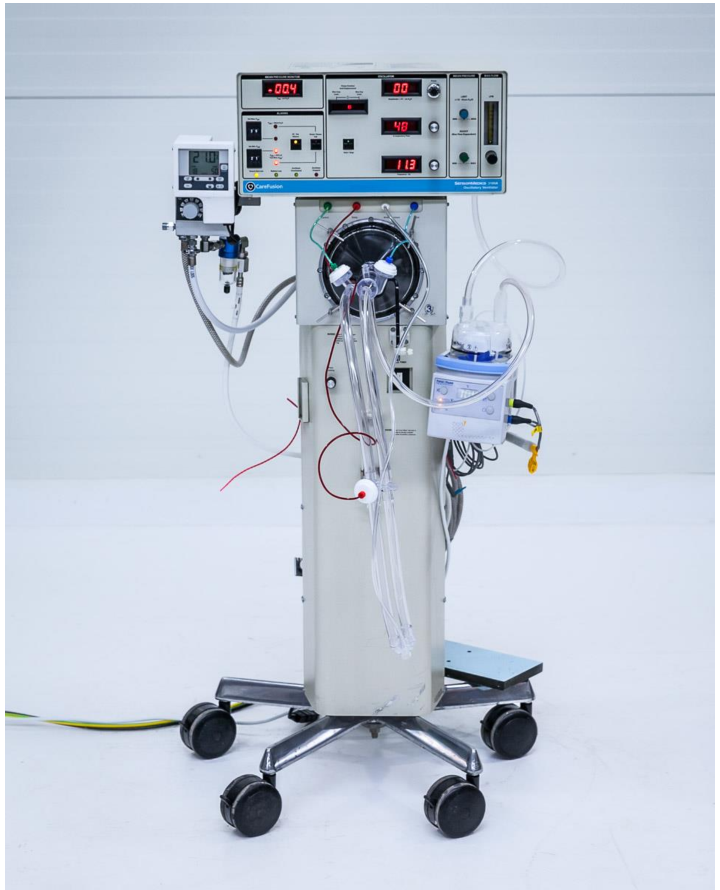


DRAGER VN 500

SLE 5000

LEONI PLUS

SENSORMEDICS 3100A

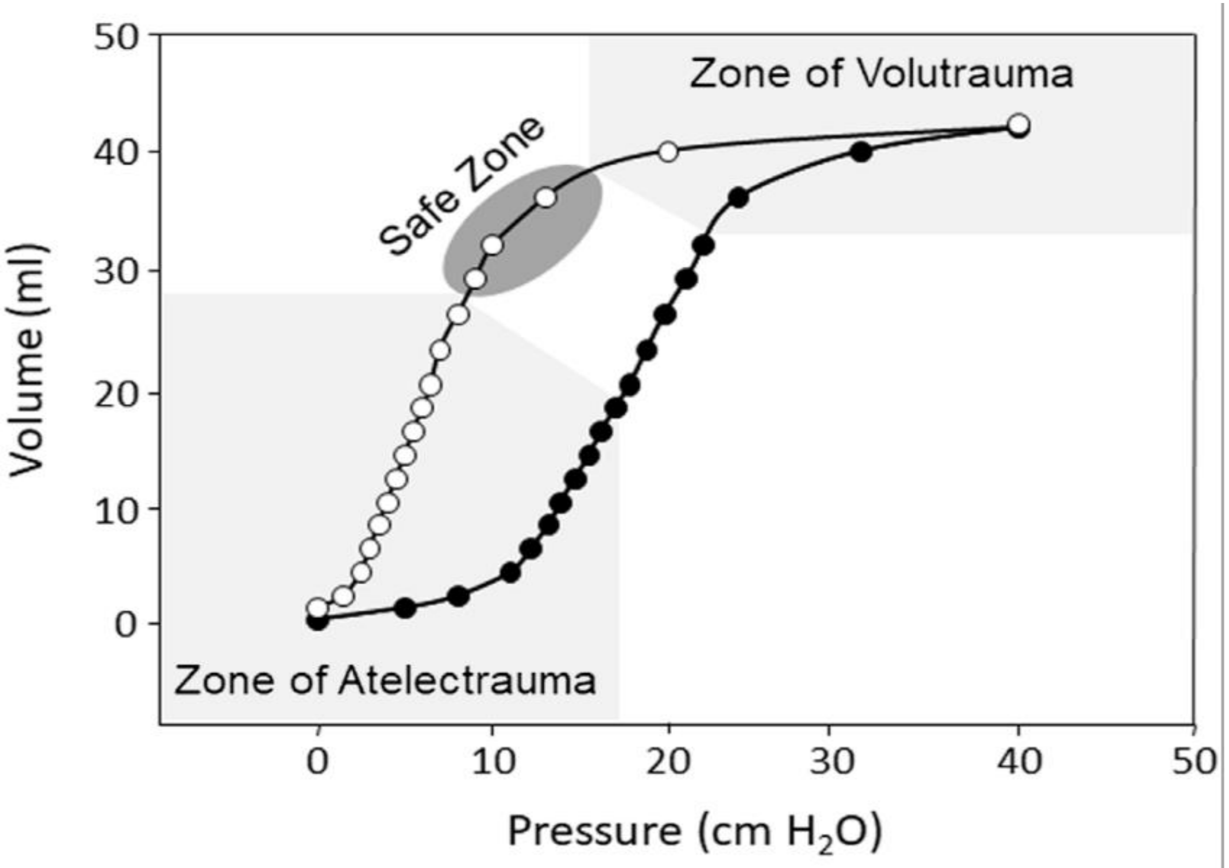


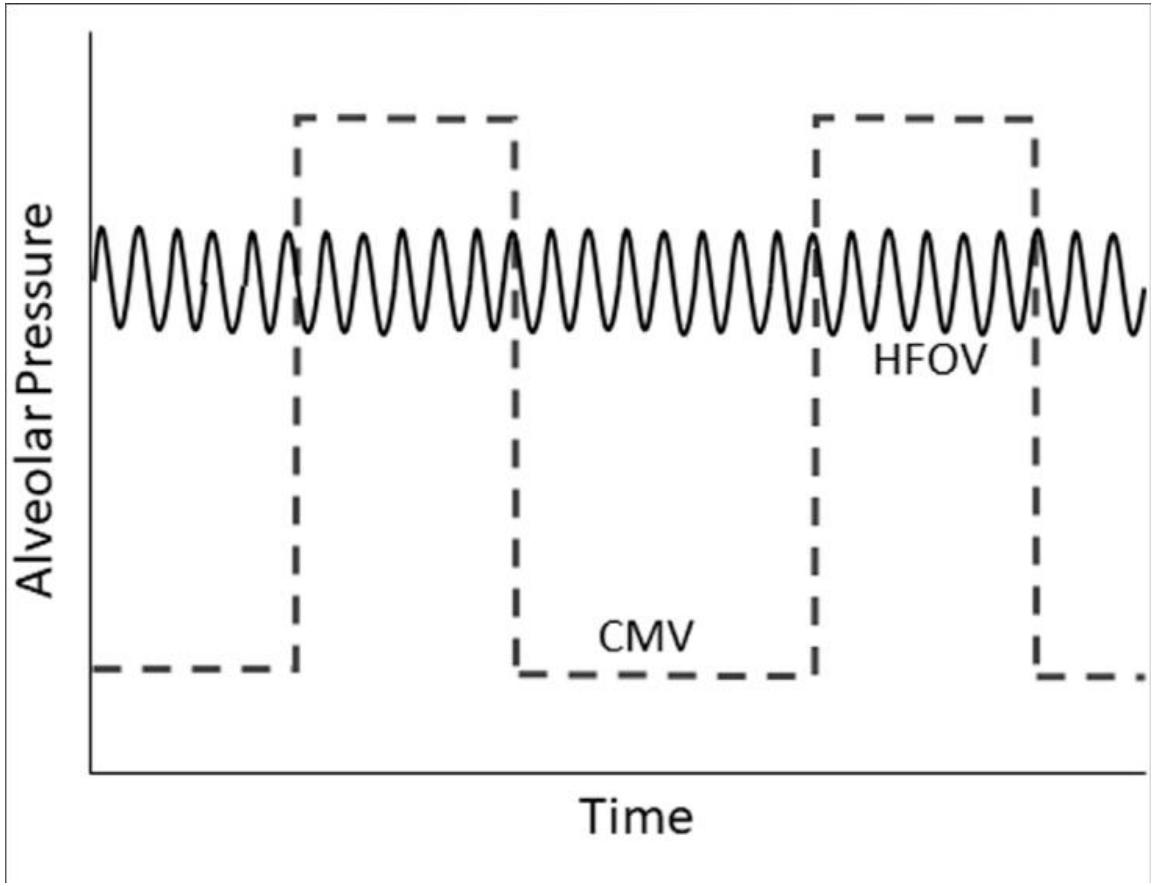
3100A- neonates, infants and children < 35 kg

3100B - > 35 kg

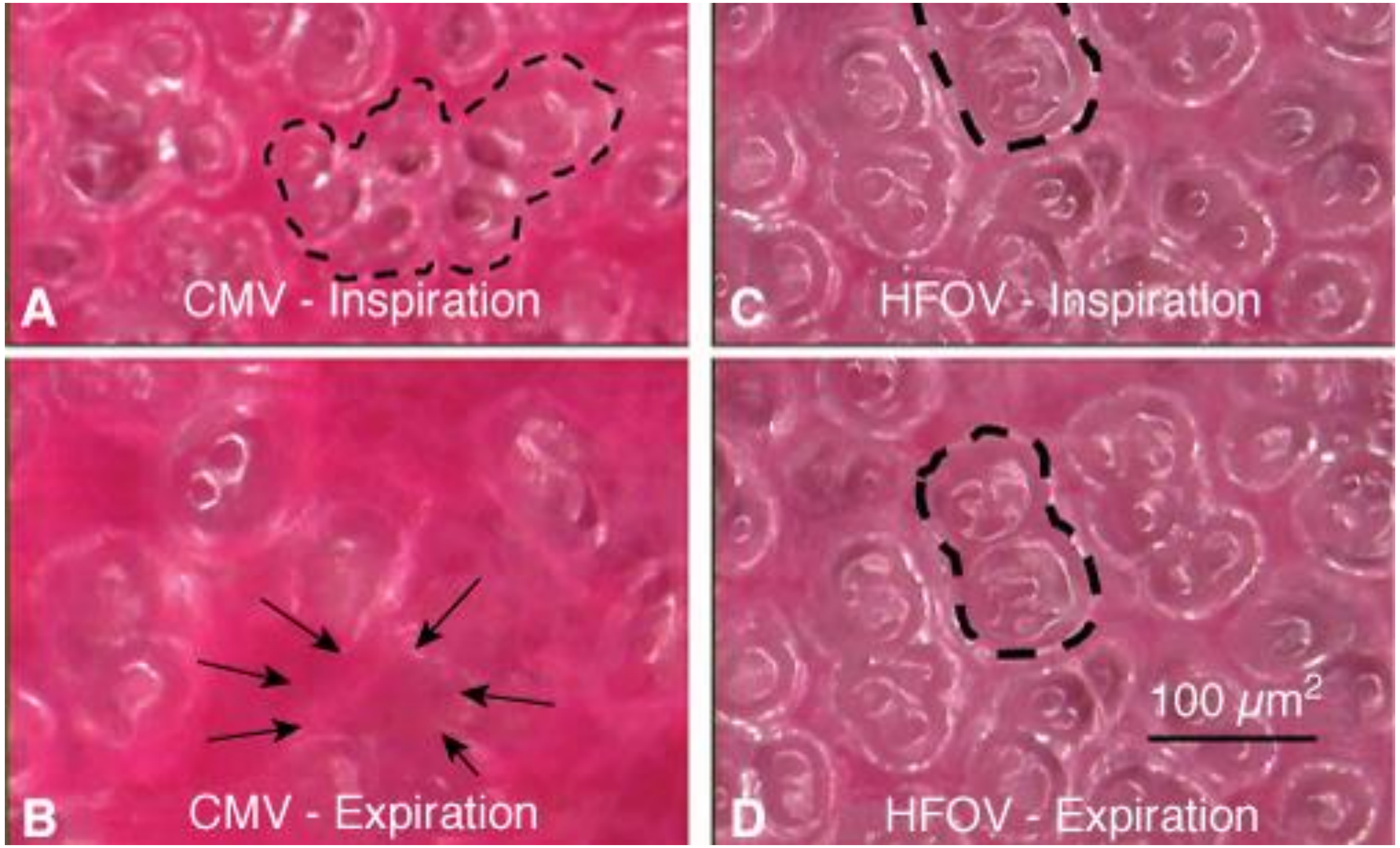
Advantages of HFOV over CMV

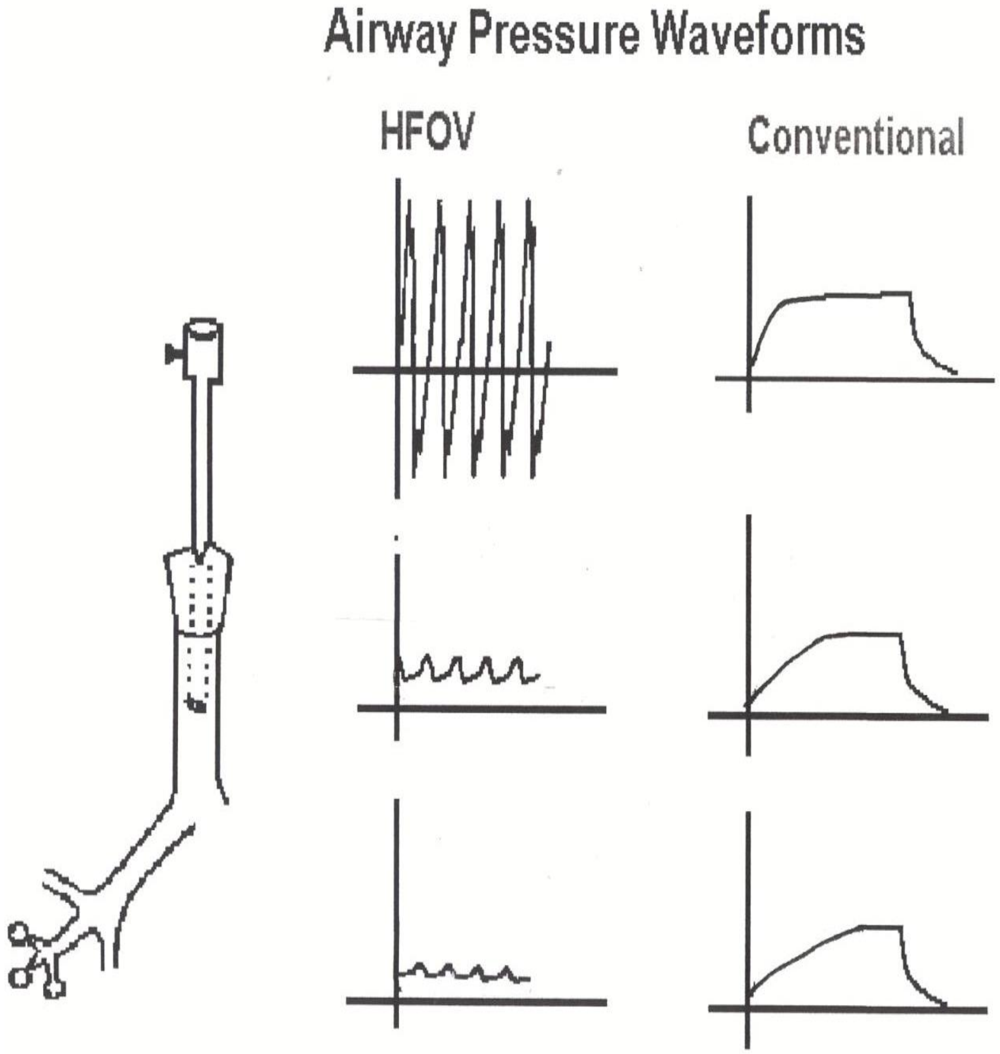
1. Small tidal volume – prevents alveolar overdistension and trauma
2. Higher mean airway pressure – improved alveolar recruitment
3. Smaller gradient between inspiratory and expiratory pressures – less atelectotrauma
4. Low peak pressures – reduce barotrauma





HFOV - a Constant MAP is maintained which prevents the over-inflation-deflation of alveoli which produces lung injury.


A
CMV - Inspiration
C
HFOV - Inspiration
B
CMV - Expiration
D
HFOV - Expiration
100 μm²

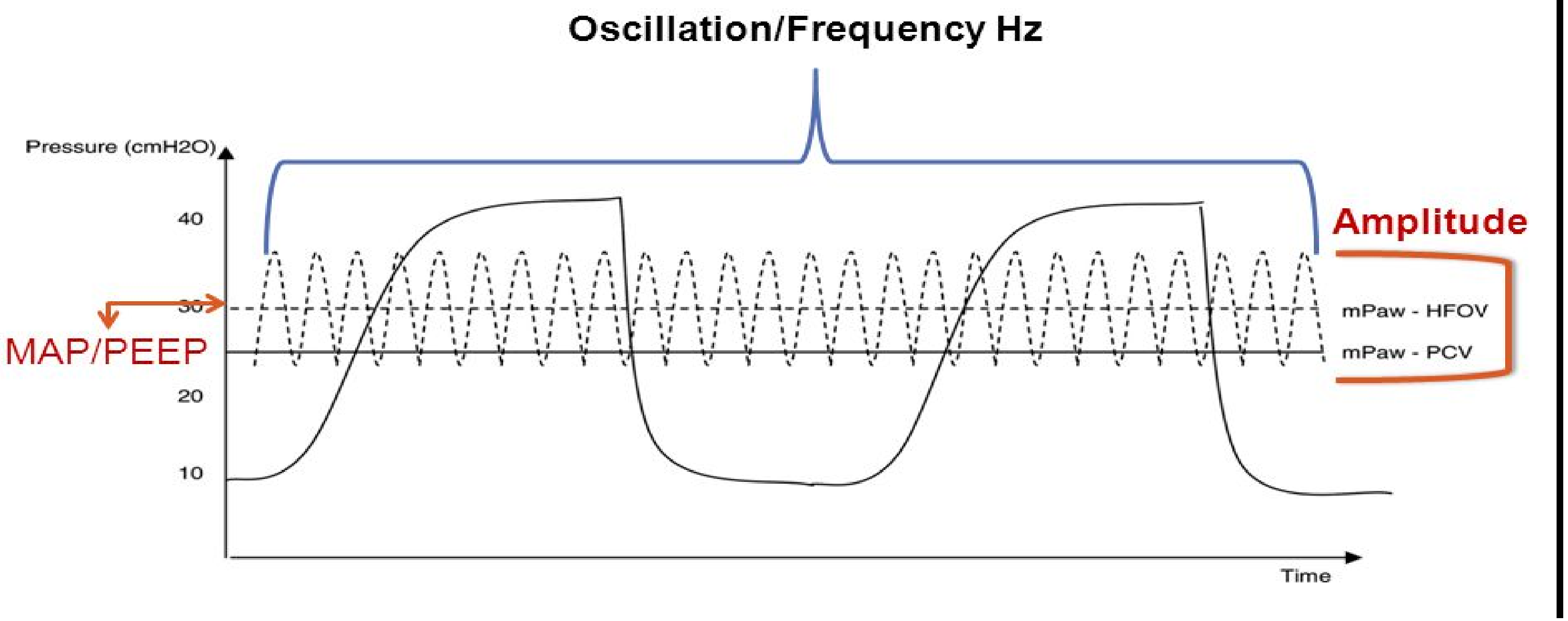


- In CMV, pressure exerted by the ventilator propagates through the airway with little dampening.

- In HFOV there is attenuation of pressures as air moves towards alveolar level

VENTILATOR SETTINGS

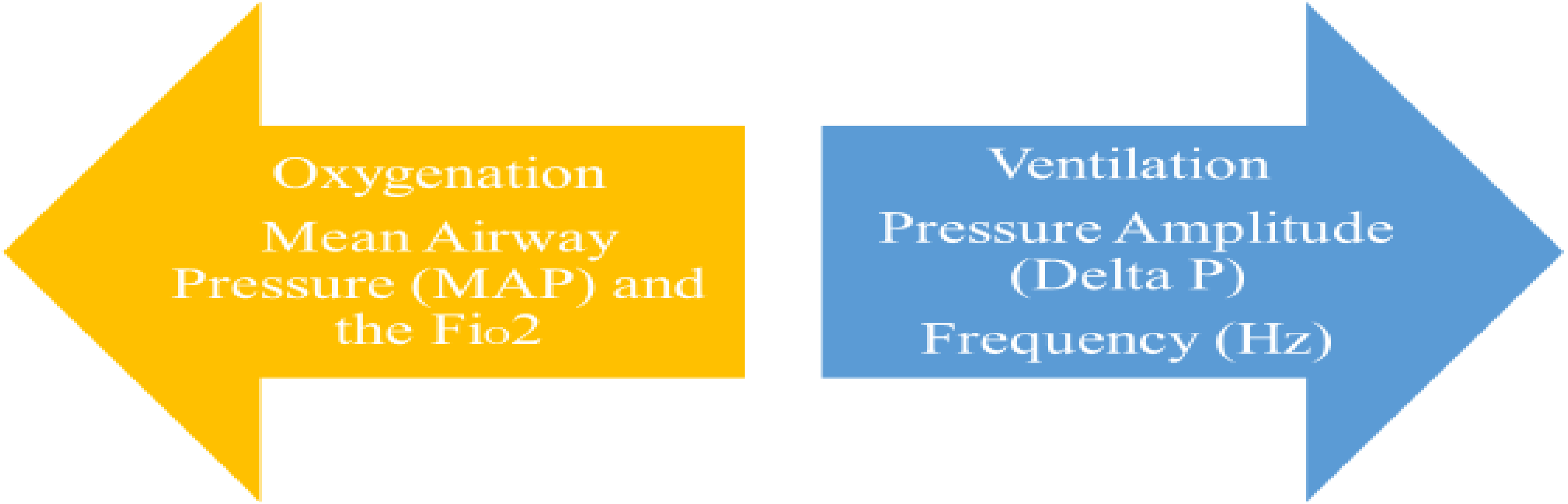
CONVENTIONAL	HFOV
PIP	MAP
PEEP	Amplitude/Power/Delta P
FiO2	Rate in Hertz
Rate	FiO2
I Time	



INITIAL SETTINGS IN HFOV

- **Mean Airway Pressure** – Start with a MAP around 2-3 higher/lower than the MAP required during CMV
- **Amplitude -** Start with twice the MAP
- **Frequency** – 10 – 12 Hz
- **I:E ratio** – 1:2

HFOV Decouples Oxygenation from ventilation



OXYGENATION

Mean Airway Pressure

- A constant pressure used to inflate the lung and hold the alveoli open

- Optimum MAP should achieve lung inflation as seen on CXR to the 8^{th}-9^{th} rib at the level of the patient's diaphragm

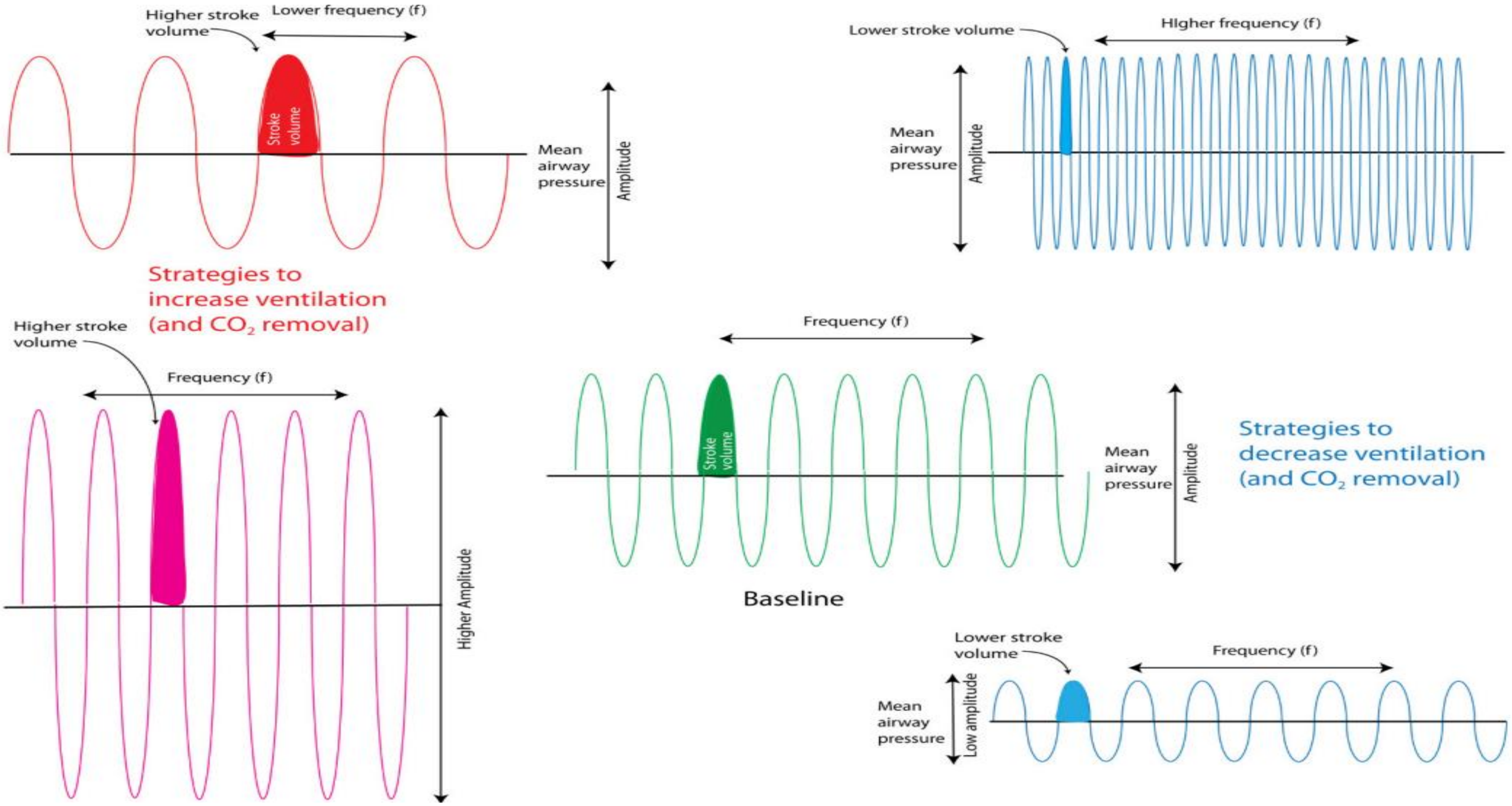
VENTILATION

1. **Amplitude:**

- Primary control of PaCO2
- Increase Delta P – Fall in PCo2 and vice-versa
- Adjusts the distance that the piston moves, resulting in a volume displacement and visual - wiggle / wobble

2. FREQUENCY

- Controls the time allowed (distance) for the piston to move
- The **higher the frequency, the smaller the volume displaced** and vice - versa


Higher stroke volume
Lower frequency (f)
Stroke volume
Mean airway pressure
Amplitude
Lower stroke volume
HIgher frequency (f)
Mean airway pressure
Amplitude
Strategies to increase ventilation (and CO_2 removal)
Higher stroke volume
Frequency (f)
Higher Amplitude
Frequency (f)
Stroke volume
Mean airway pressure
Amplitude
Strategies to decrease ventilation (and CO_2 removal)
Baseline
Lower stroke volume
Frequency (f)
Mean airway pressure
Low amplitude

- Alveolar ventilation during CMV is defined as:

$$F \times Vt$$

- Alveolar Ventilation during HFVO is defined as:

$$F \times Vt^2$$

- Therefore, changes in volume delivery (as a function of Delta-P, Freq) have the most significant affect on CO_2 elimination

- ***Hypoxia***: Increase MAP (Max 25 – 30) (by 1-2 cm H_2O)
  Increase FiO_2
- ***Hyperoxia*** Reduce FiO_2
  Decrease MAP carefully
- ***Hypercapnia*** Increase amplitude (3-5 cm H_2O)
  Decrease frequency (1- 2 Hz)
- ***Hypocapnia*** Decrease amplitude
  Increase frequency

WEANING FROM HFOV

- Reduce FiO2 to <40% before weaning MAP(except when overinflation)
- Reduce MAP when overinflation
- Reduce MAP in 1-2 cm H2O decrements to 8-10 cm H2O
- In air leak syndromes, reducing MAP> weaning FiO2
- Wean amplitude/ do not wean frequency
- Discontinue weaning, when MAP 8-10 cm H20 and Amplitude 20-25
- Stable, oxygenating well and ABG is normal

EVIDENCE

CLINICAL TRIAL OF HFOV (PRESURFACTANT)

Author and year	Number of patients	Characteristics of study group	results
HiFi, 1989	673	Resp failure, 750-2000 g (mean – 1100 g)	HFOV did not decrease CLD
Clark, 1992	83	RDS, ≤ 1750 g (mean 1100g)	HFOV decreased CLD compared with CV
HiFO, 1993	176	Severe RDS, ≥ 500 g (mean 1700g)	HFOV decreased rate of new air leak compared with CV
Ogawa, 1993	92	Resp failure, 750-2000g (mean – 1200g)	HFOV did not improve outcome (outcome excellent in both groups)

TRIALS OF HFV IN SURFACTANT ERA BUT BEFORE SYNCHRONISATION

Author and year	Number of patients	Charactersitics	Results
Gerstmann, 1996	125	RDS, ≤35 wk (mean 1500g)	HFOV improved survival without CLD, reduced surfactant needs, decreased hospital costs
Wiswell 1996	73	RDS, <33 wk, >500g (mean 945g)	HFJV did not improve pulmonary outcome
Keszler, 1997	130	RDS, ≤ 35 WK, 700 to 1500g (mean 1020g)	HFJV reduced incidence of CLD at 36 wk corrected age and need for home oxygen

TRIALS OF HFV IN SURFACTANT ERA AFTER SYNCHRONISATION

Author and year	Number of patients	Characteristics	Results
Moriette, 2001	273	RDS, 24 to 29 wk (mean 986 g)	HFOV reduced need for surfactant but did not improve pulmonary outcome
Courtney 2002 (NVSG)	**498**	**RDS, 601 to 1200 g (mean 855 g), < 4 h**	**HFOV decreased age at extubation, increased survival without CLD**
Johnson 2002 (UKOS)	**797**	**Needing ventilation, 23 to 28 wk, <1 h (mean 726 g)**	**HFOV did not improve pulmonary outcome**
Craft 2003	46	RDS, <1000 g (mean, 726 g)	HFOV did not decrease CLD. Trend to more air leak
Van Reempts 2003	300	RDS, GA < 32 wk (mean 1195 g)	HFOV did not improve pulmonary outcome

The 2002 HFOV RCTs

Courtney et al. N Eng J Med 2002;347:643-52 (NVSG)

Johnson et al. N Eng J Med 2002;347:633-42 (UKOS)

HFOV n= 232	SIMV n=250	PARAMETER	HFOV n=400	SIMV n= 397
860	849	Mean BW (gms)	844	863
26.1	26	Mean GA (weeks)	26.5	26.5
14%	16%	Mortality	25%	26%
30%	37%	O2 at 36wks	41%	41%
57%	47%	Alive without BPD @ 36 weeks	34%	32%
22%	23%	Severe IVH/PVL	14%	19%

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[Intervention Review]

Rescue high frequency oscillatory ventilation versus conventional ventilation for pulmonary dysfunction in preterm infants

Tushar Bhuta[1], David J Henderson-Smart[2]

- **OBJECTIVES:**

To determine the effects of HFOV compared to conventional ventilation on pulmonary air leak and CLD in preterm infants with very severe lung disease requiring ventilation

- **SELECTION CRITERIA:**

Randomised controlled trials of HFOV vs. CV as rescue therapy in preterm infants with severe pulmonary dysfunction

Results:

- Only one trial was found and this showed that rescue HFOV caused a reduction in any new pulmonary air leak (PAL)
- There was no significant effect on mortality at 30 days.
- The rate of (IVH) of any grade was increased in infants treated with HFOV
- There was a stronger, but non-significant trend towards an increase in severe IVH (grades 3 or 4 IVH)

Conclusions:

- There is insufficient information on the use of rescue HFOV to make recommendations for practice.
- The small amount of data that exists suggest that harm might outweigh any benefit.
- Any future use of HFOV as rescue therapy for preterm infants with severe RDS should be within randomised controlled trials and address important outcomes such as longer term pulmonary and neurological function.

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Elective high frequency oscillatory ventilation versus conventional ventilation for acute pulmonary dysfunction in preterm infants

Filip Cools, Martin Offringa, Lisa M Askie Authors' declarations of interest

Version published: 19 March 2015 Version history

https://doi.org/10.1002/14651858.CD000104.pub4

- **Objectives:**

The objective of this review was to determine the effect of the elective use of high frequency oscillatory ventilation (HFOV) as compared to conventional ventilation (CV) on the incidence of chronic lung disease (CLD), mortality and other complications associated with prematurity and assisted ventilation in preterm infants who were mechanically ventilated for respiratory distress syndrome (RDS).

- **Selection criteria:**

Randomised controlled trials comparing HFOV and CV in preterm or low birth weight infants with pulmonary dysfunction, mainly due to RDS, who required assisted ventilation. Randomisation and commencement of treatment needed to be as soon as possible after the start of CV and usually in the first 12 hours of life.

Results:

- Nineteen eligible studies involving 4096 infants were included.
- **No evidence of effect on mortality at 28 to 30 days of age or at approximately term equivalent age.** These results were **consistent across studies and in subgroup analyses.**
- The **risk of CLD** in survivors at term equivalent gestational age was significantly reduced with the use of HFOV but this effect was **inconsistent across studies.**
- **Pulmonary air leaks**, occurred **more frequently in the HFOV group**, whereas the risk of severe retinopathy of prematurity was significantly reduced.
- **No significant differences** in effect on incidence of IVH and PVL between HFOV and CV.

CONCLUSIONS:

- Evidence that the use of elective HFOV compared with CV results in a small reduction in the risk of CLD, but the evidence is weakened by the inconsistency of this effect across trial.
- The benefit could be counteracted by an increased risk of acute air leak
- Adverse effects on short-term neurological outcomes have been observed in some studies but these effects are not significant overall.
- Most trials reporting long-term outcome have not identified any difference.

NEW STRATEGY – HFOV + VG

- Targeting TV in conventional ventilators – improved outcomes in terms of mortality, IVH, BPD, cystic PVL, pneumothorax, hypocapnia

- DCO2 – relatively new marker of alveolar ventilation during HFOV

Related to high frequency expired TV (VThf)

VThf – tidal volume in HFOV

- Generated by fluctuations of pressure around MAP

VThf increases if:

- Amplitude increases
- Frequency decreases

Also varies with:

- ET tube size
- Compliance of the tubing
- Performance of the ventilator
- Lung conditions

- VThf fluctuates widely during HFOV,

LEADING TO UNEXPECTED VARIATIONS OF CO_2 REMOVAL…….

Hypocapnia: PVL

Hypercapnia: IVH

Stable CO_2 - stable TV

- Set target VT
- Set amplitude limit
- Microprocessor adjusts amplitude to maintain stable
- Calculates based on average of several seconds

DCO2 - $VThf^2 * F$ (ml2/sec)

Lower DCO2 – CO_2 retention – Higher $PaCO_2$

Higher DCO2 – CO_2 washout – lower $paCO_2$

THANKYOU