HIGH FREQUENCY JET VENTILATION

18th Hot Topics in Neonatal Medicine

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OBJECTIVES

- What is high frequency jet ventilation?
- How does HFOV differ from HFJV?
- Is one preferable to the other?
- What might be the benefits to using HFJV as rescue & prophylactically?

HOW CAN I BREATHE?

WHAT IS HIGH FREQUENCY VENTILATION

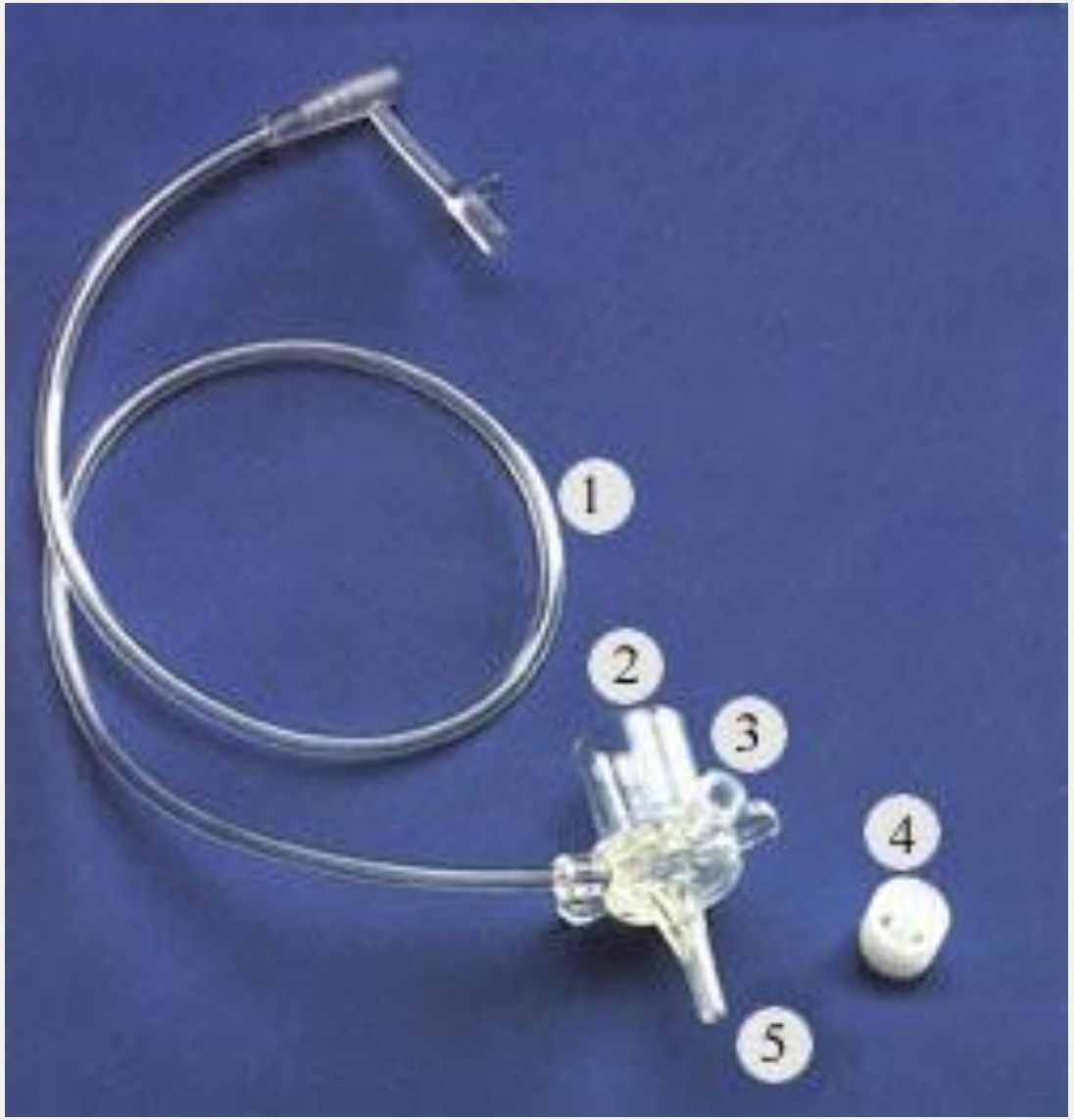
- Ventilation at rapid rates with tidal volumes < dead space volumes
  - 2 - 2.5 cc/kg
- Minute Ventilation
  - Conventional [$Ve = R \times Vt$]
  - HF ventilation [$Ve = R \times Vt^2$]

BUNNELL


MONITOR
ALARMS
READY
SERVO
CONTROLS
RATE
I-TIME
I:E RATIO
HUMIDIFIER
ALARMS
PAUSE
TEMP
GAS
WATER
AUDIO PAUSED
STANDBY
ENTER
LifePulse
HIGH FREQUENCY VENTILATOR
bunnell
GAS OUT
PURGE
WATER PUMP
BATTERY
Bunnell Hotline
800-800-4358
Customer Support
24 Hours a Day
www.bunl.com

LIFEPORT

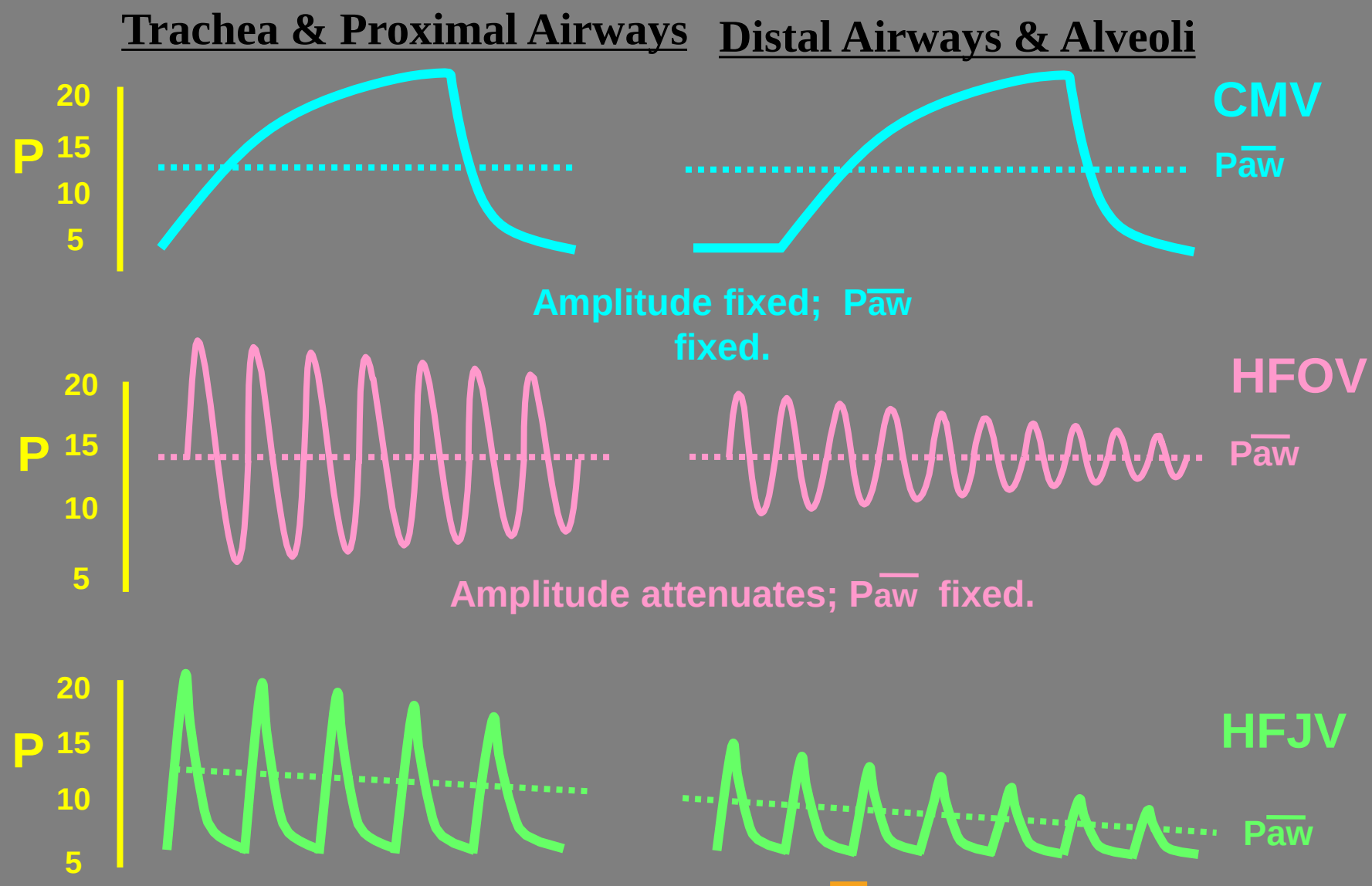
- 1 - Pressure monitoring line
- 2 - 15 mm connection to CMV
- 3 - Jet port
- 4 - Jet port cap
- 5 - ET connection



LIFE PULSE *"PATIENT BOX"* ENHANCES FLOW STREAMING.

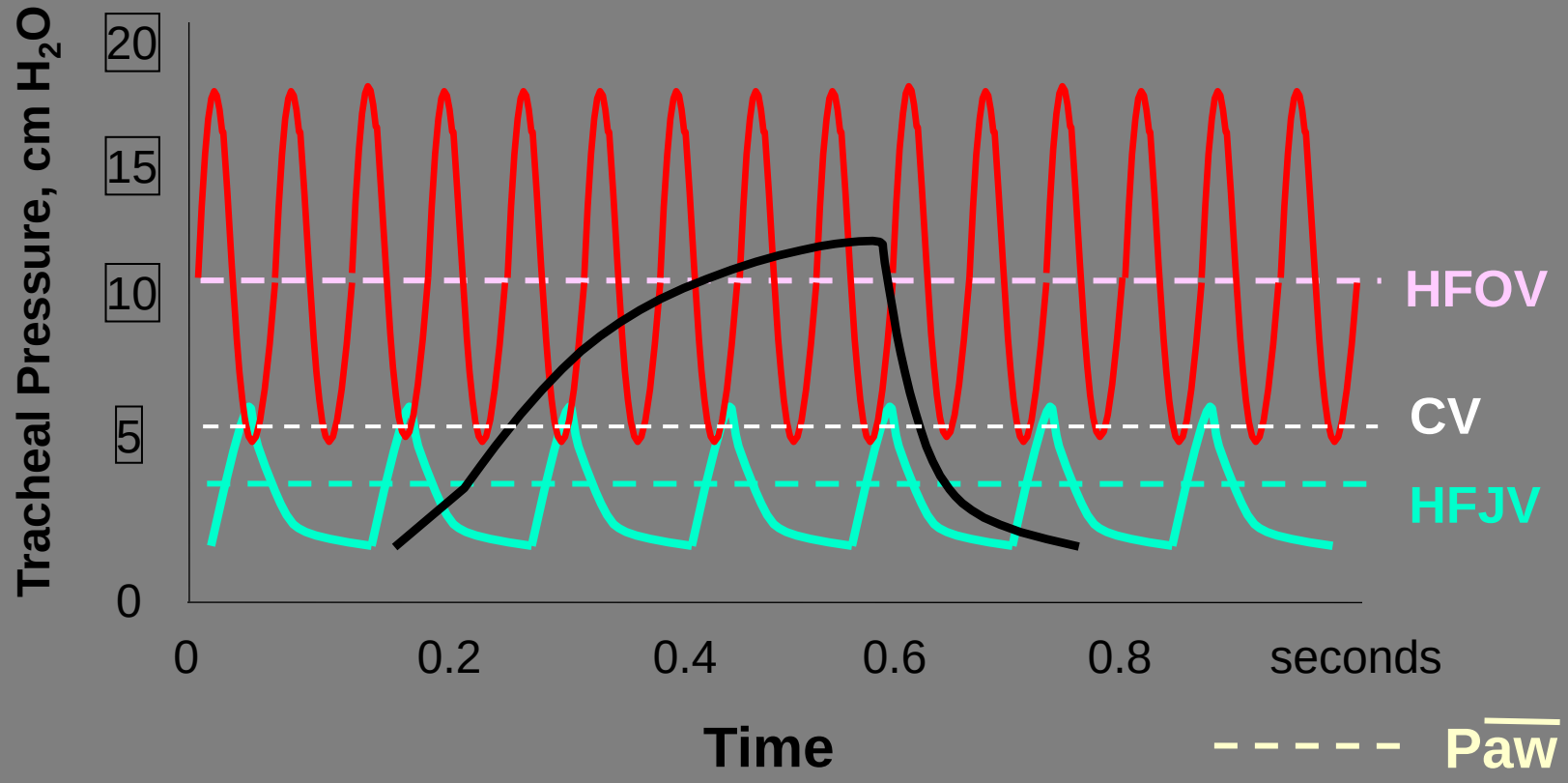
- **Humidifying gas before the pinch valve and locating it close to patient**
- **minimizes compressible volume.**

HFV Pressure Attenuation



PRESSURE WAVEFORM COMPARISON

Three Ventilators, Same Blood Gases



Boros, et al. Ped Pulm. 1989; 7:35-41

TYPICAL SETTINGS

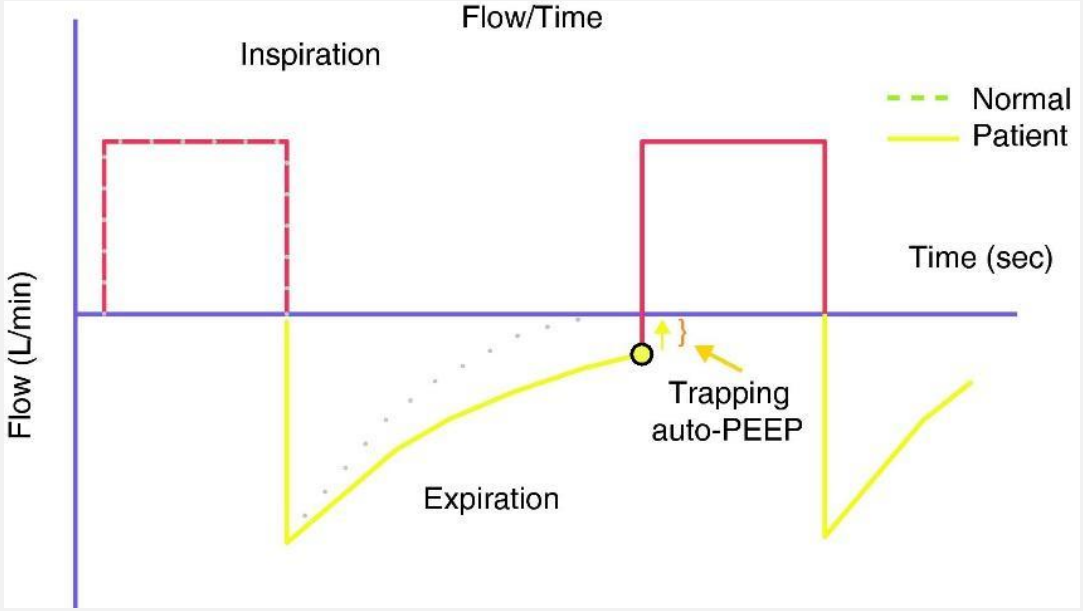
- Rates 240 - 660 BPM
- Ti 0.02
- PIP and rate are adjusted for CO_2 clearance
  - Higher rates = ↓ CO_2
  - Lower rates = ↓ MAP

HFOV VS HFJV

Device	Rate (Hz)	I/E	Ti	Exhalation	CV	ETT adapter
HFJV	4-11	1:11 to 1:3	0.02	Passive	Yes	yes
HFOV	3-15	1:2 to 1:1	0.1 - 0.02	Active	No	No

HFJV VS HFOV

- Allows separation of alveolar recruitment from alveolar stabilization
- Set PEEP , Flow ,and recruitment breaths CMV
- Allows detection of inadvertent peep
- Set PEEP on CMV / Measure peep at JET



THE IMPORTANCE OF SERVO PRESSURE

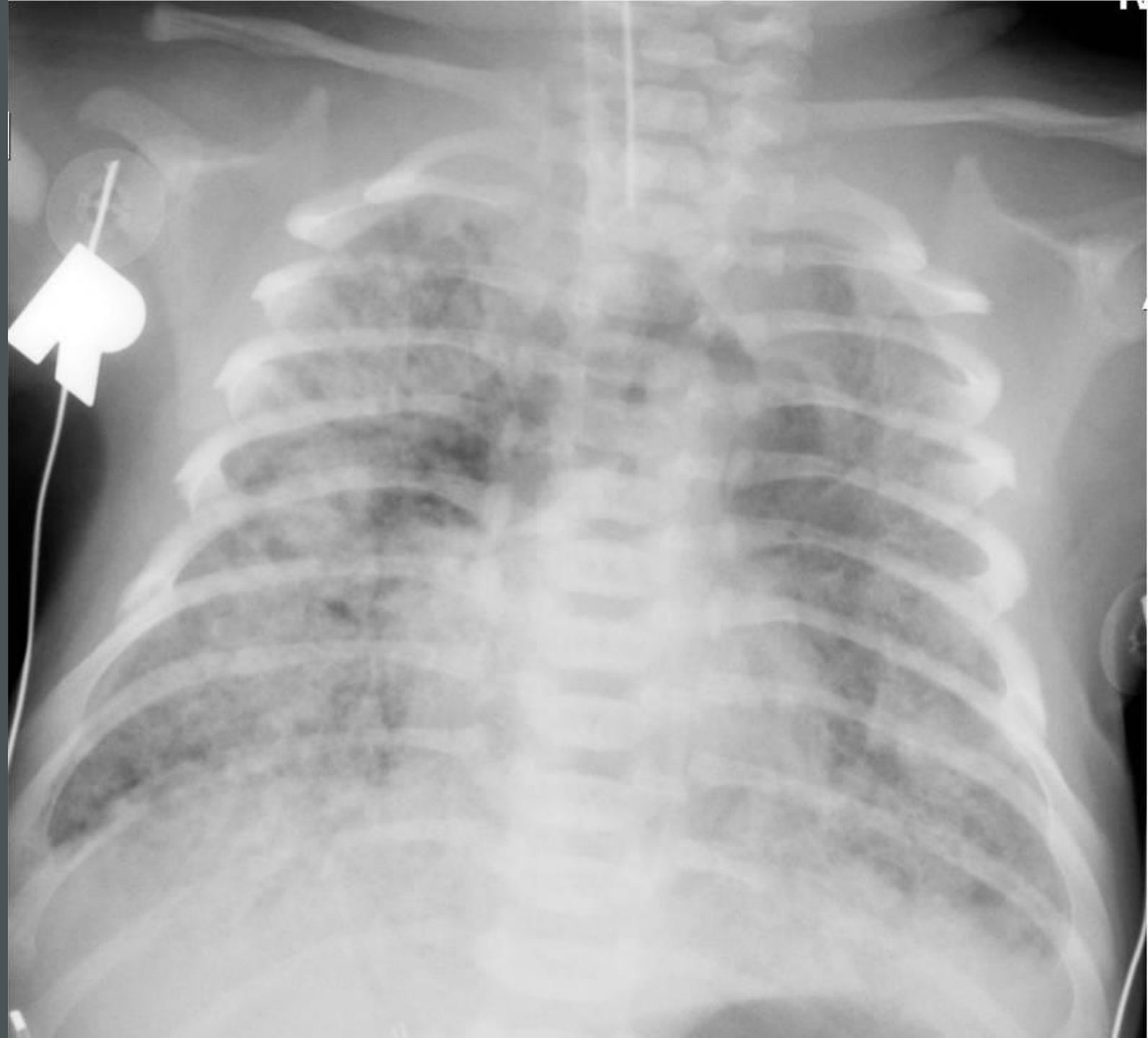
- Servo Pressure = Automatically controlled Driving Pressure.
- Servo pressure changes as lung volume changes.

- Servo pressure changes give early warning to patient's changing clinical conditions.

INCREASES	DECREASES
• ↑ compliance and/or resistance	• ↓ compliance and/or resistance
• Increased air leak	• Tension pneumothorax
• Leaky tubing	• Patient needs suctioning

WHEN MIGHT YOU USE IT?

- HFOV suited for homogenous disease.
  - ARDS
  - RDS
- The JET works with homogenous diseases, but is optimized in heterogeneous diseases.
  - Pneumonia (+++ Secretions)
  - MAS
  - Air Leaks



WHAT DOES THE RESEARCH SAY?

USE AS A RESCUE FOR PIE?

144 infants: 750 - 2000g

PIE on CMV

RCT to HFJV or HF CMV

- Cross over (65% CMV to HFJV, 39% HFJV to CMV)
- Primary outcome success or failure of the originally assigned therapy and response to the alternate therapy after crossover.

Treatment success

- Resolution of PIE for ≧ 24 hours
- Substantial x-ray improvement and reduction in MAP to 40% less than baseline values

Keszler M, J Pediatr 1991

RESULTS

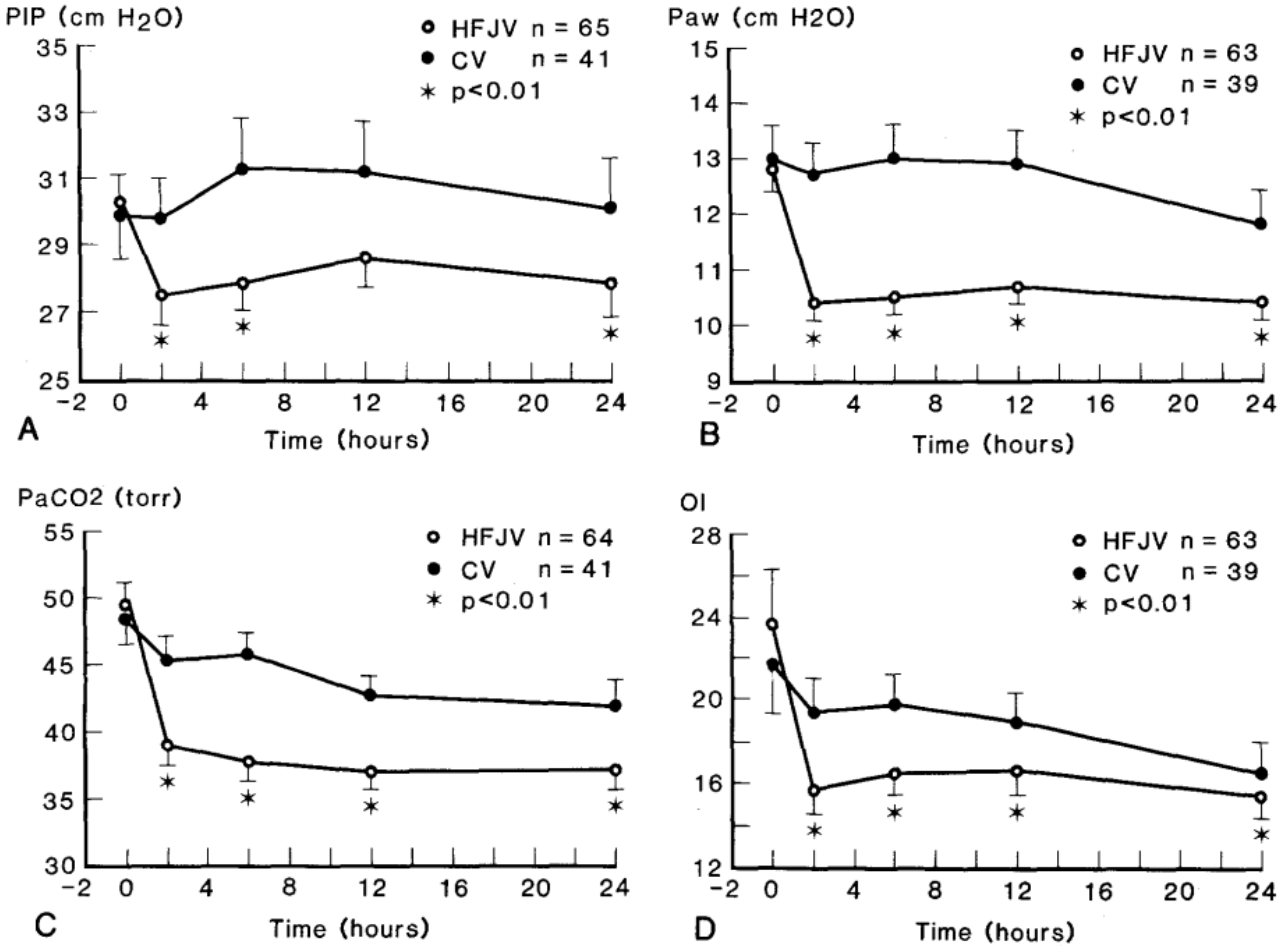


Fig. 1. Peak inspiratory pressure (**A**), mean airway pressure (**B**), $PaCO_2$ (**C**), and oxygenation index (**D**) for the first 24 hours of the study. Data are expressed as mean ± SEM.

RESULTS

Table III. Response to therapy

	CV		HFJV	
	Median (Range)	n	Median (Range)	n
Time to improve PIE (hr)	53 (4-160)†	27	33 (2-144)†	44
Time to resolve PIE (hr)	70.5 (8-208)	24	75 (12-235)	33
Time to failure (hr)	8.5 (0.5-86)*	40	57 (2-242)*	23
Time to extubation (hr)	340 (87-5040)	32	325 (90-1764)	41

Table IV. Success of therapy, survival, and complications by birth weight

	Birth weight (gm)								
	<1000			1000-1500			>1500		
No. of cases	CV 24	HFJV 26	Total* 50	CV 25	HFJV 24	Total* 49	CV 21	HFJV 24	Total* 45
Success (%)	33	46	40	28†	63†	45	52	75	64
Survival (%)‡	33	35	40	44†	79†	78	57	83	87
BPD (%)	91	67	80	78	70	73	42	25	33
Alive, free of BPD (%)	4	12	8	16	25	20	52	63	58
IVH grades III, IV (%)	40	43	41	41	27	34	9	4	6

NEAR TERM AND TERM INFANTS WITH PPHN?

- >2000 g and > 35 weeks
- FiO2 1.0
- PPHN, MAS, aspiration, RDS, TTN
- All patients given trial of HF CMV then randomized to HFJV or continued HF CMV
- Failure
  - Need for ECMO or death

Engle WA et al, J Perinatol 1997;17:3

PROBLEMS

No power calculation

Study stopped early due to lack of a survival advantage and initiation of iNO study

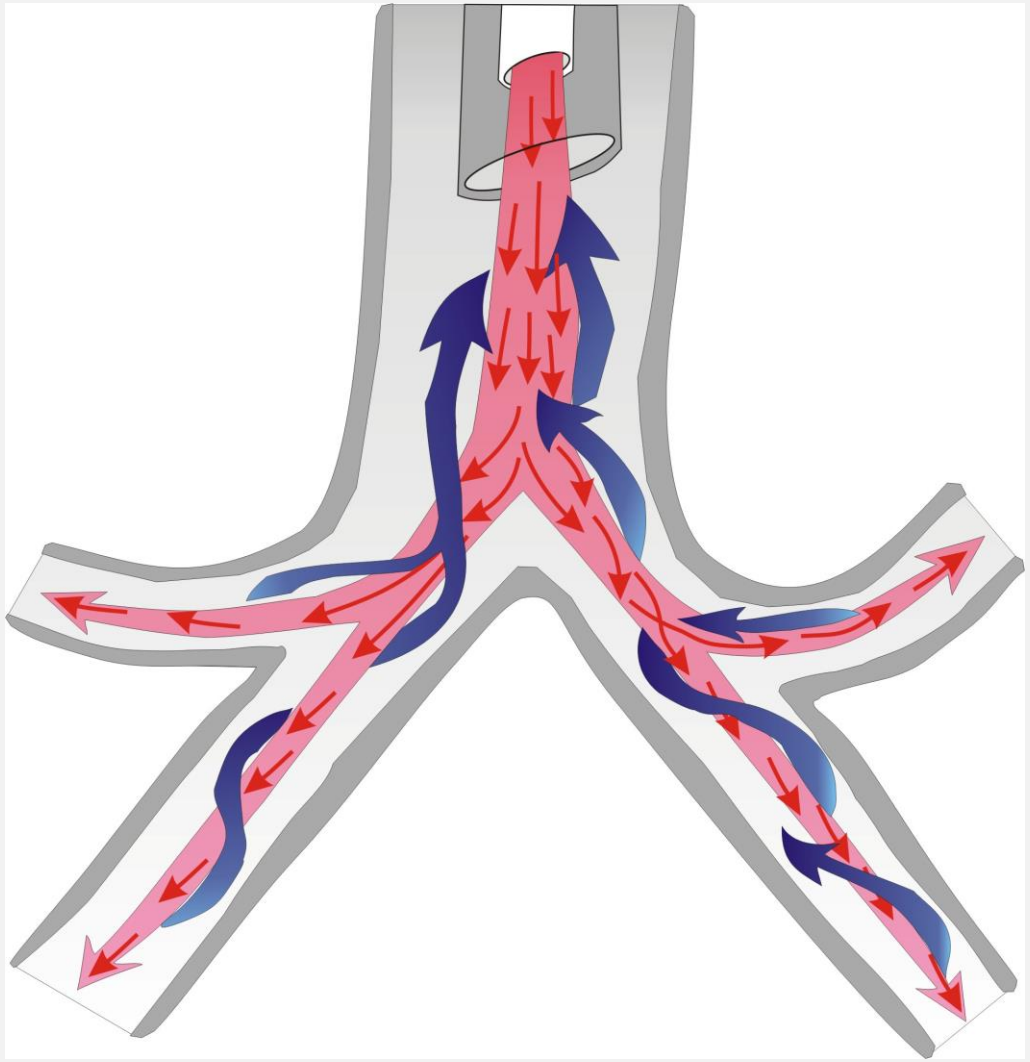
THEY WERE ALMOST THERE!

	HFJV (11)	Control (13)	p
CLD (in survivors)	0/9	4/10	0.08
O2 (d)	16.1 ± 8.2	36.8 ± 48.2	0.72
Ventilation (d)	11.8 ±8.2	24.1 ±46.2	0.83
ECMO	4	10	0.11

USE IN AIR LEAKS?

- Theoretical benefits
  - MAP largely determined by PEEP due to short Ti
  - Paw decreases distal to the proximal port of the endotracheal tube
    - Differs from HFOV where MAP is maintained due to active exhalation
  - Once expansion achieved PIP rapidly ↓

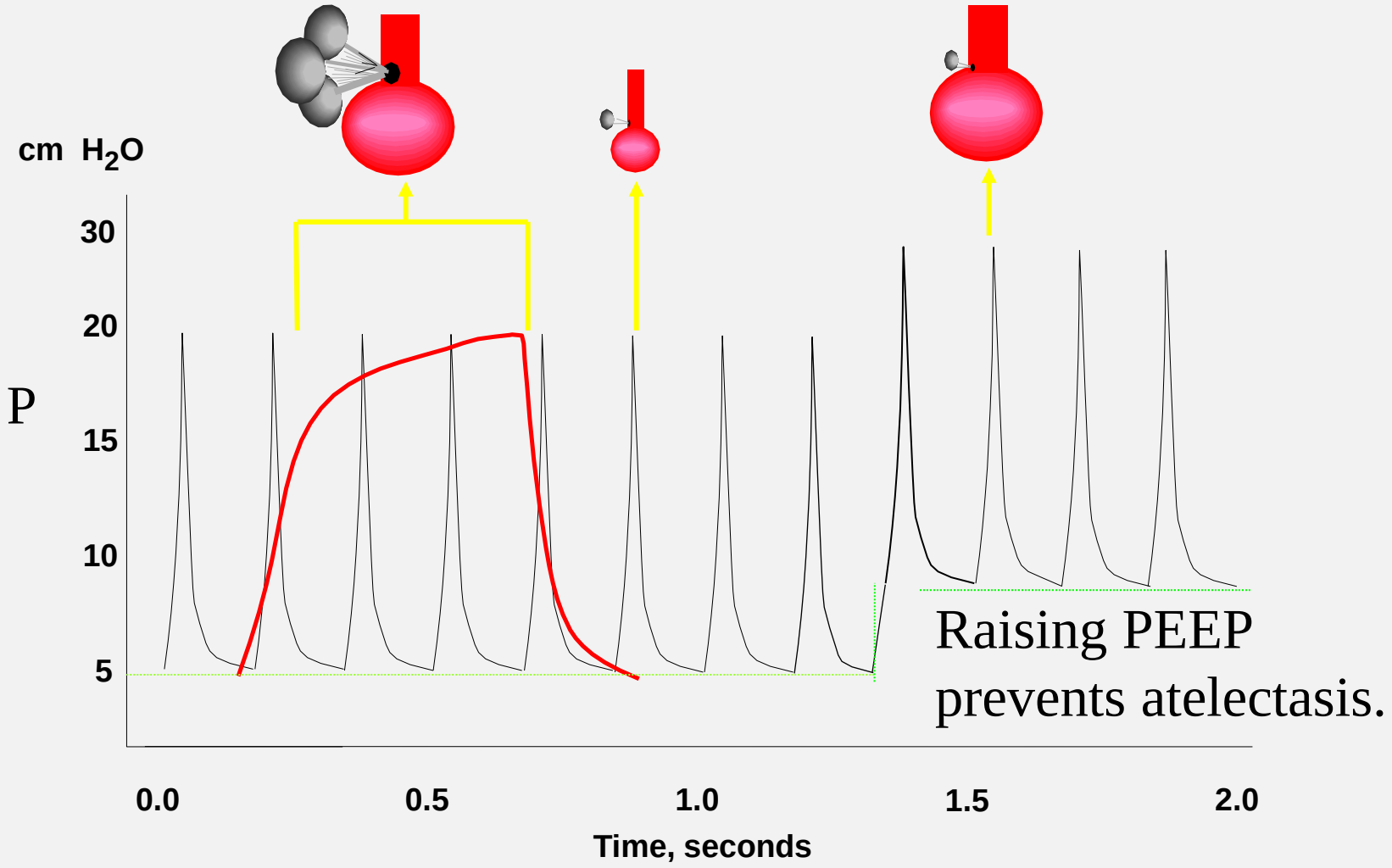
USING HFJV TO TREAT TEF & BPF



High velocity gas shoots right past upper airway leaks

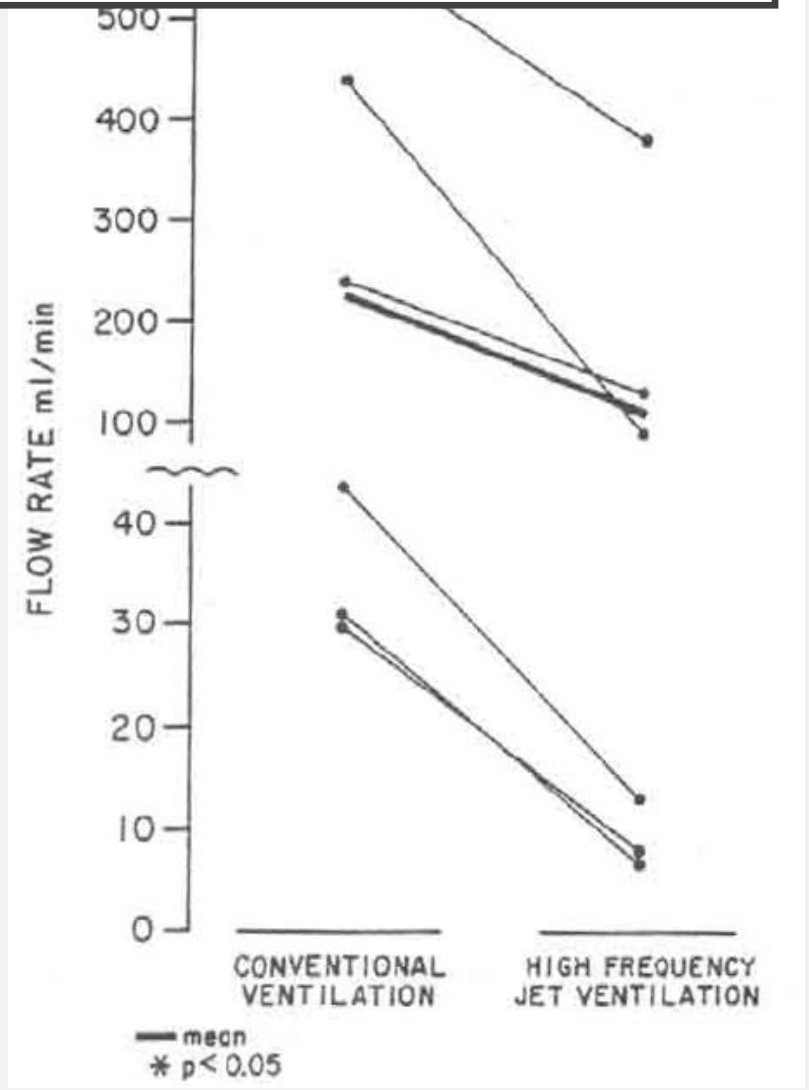
Bunnel

HFJV reduces flow out of air leaks.



CLINICAL EVIDENCE

- 6 patients with pneumothoraces and chest tubes
- All changed from CMV to HFJV
- Measurements after two hours on HFJV
  - Gonzales F, J Pediatr 1987



HFOV VS HFJV

NO RCTS COMPARING THE TWO

Cochrane Database Syst Rev. 2016 May; 2016(5): CD010548. Published online 2016 May 6.
doi: 10.1002/14651858.CD010548.pub2

PMCID: PMC6769183 | PMID: 27149997

High frequency jet ventilation versus high frequency oscillatory ventilation for pulmonary dysfunction in preterm infants

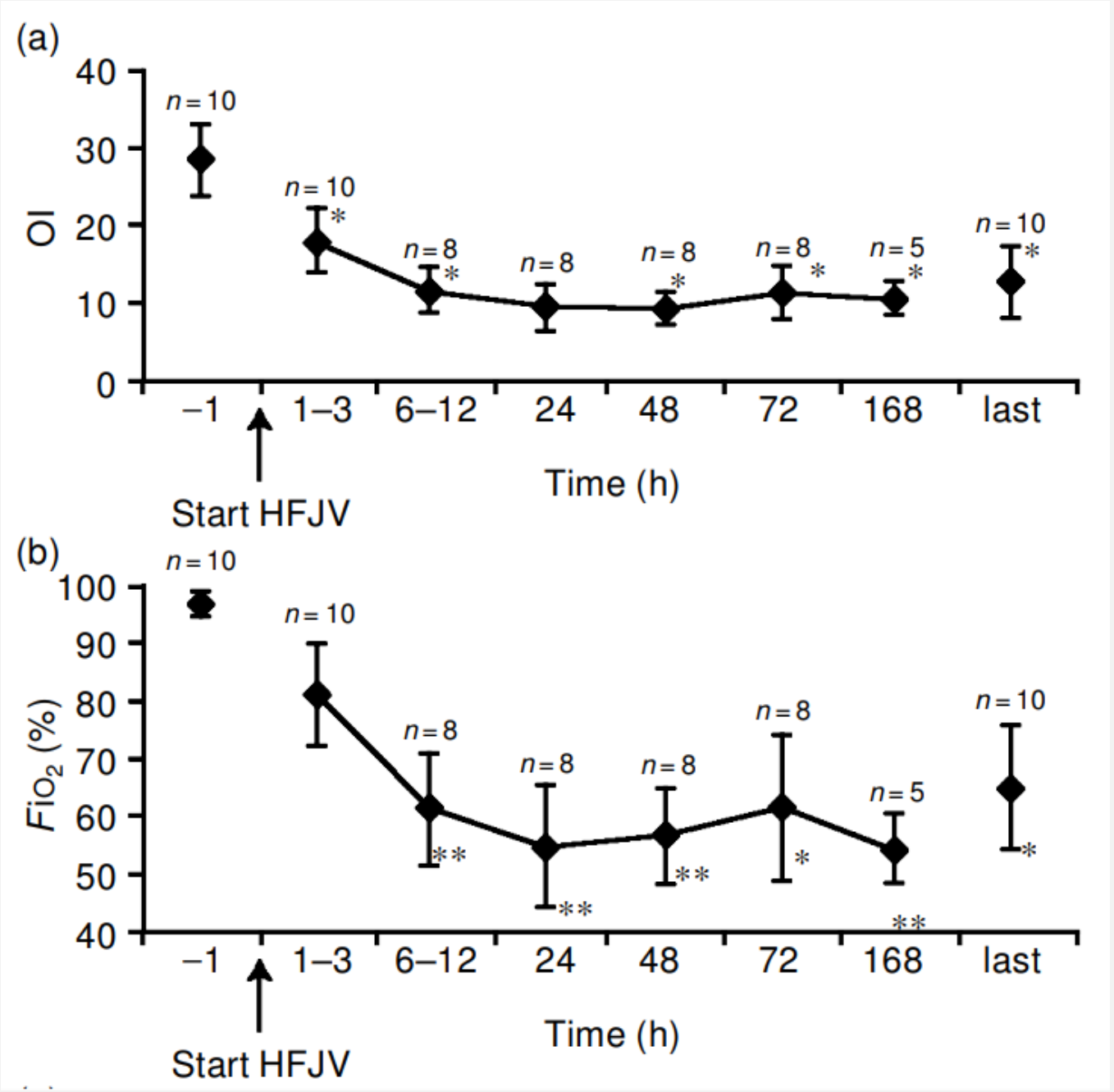
Monitoring Editor: Yahya H Ethawi,[✉] Ayman Abou Mehrem, John Minski, Chelsea A Ruth, Peter G Davis and Cochrane Neonatal Group

Use of high-frequency jet ventilation in neonates with hypoxemia refractory to high-frequency oscillatory ventilation

P. Friedlich, N. Subramanian, M. Sebald, S. Noori & I. Seri

- In CLD - long time constant
  - HFOV I:E ratio 1:2
  - Low MAP may lead to choke points
- 10 Neonates with CLD
  - Failure to oxygenate with HFOV
  - No steroids given
  - 23- 28 weeks GA at birth
  - Required OI of 20

Friedlich P, J Matern Fetal Neonatal Med 2003


(a)
OI
40
30
20
10
0
n = 10
n = 10
n = 8
n = 8
n = 8
n = 8
n = 5
n = 10
*
*
*
*
*
*
*
–1
1–3
6–12
24
48
72
168
last
Time (h)
Start HFJV
(b)
FiO_2 (%)
100
90
80
70
60
50
40
n = 10
n = 10
n = 8
n = 8
n = 8
n = 8
n = 5
n = 10
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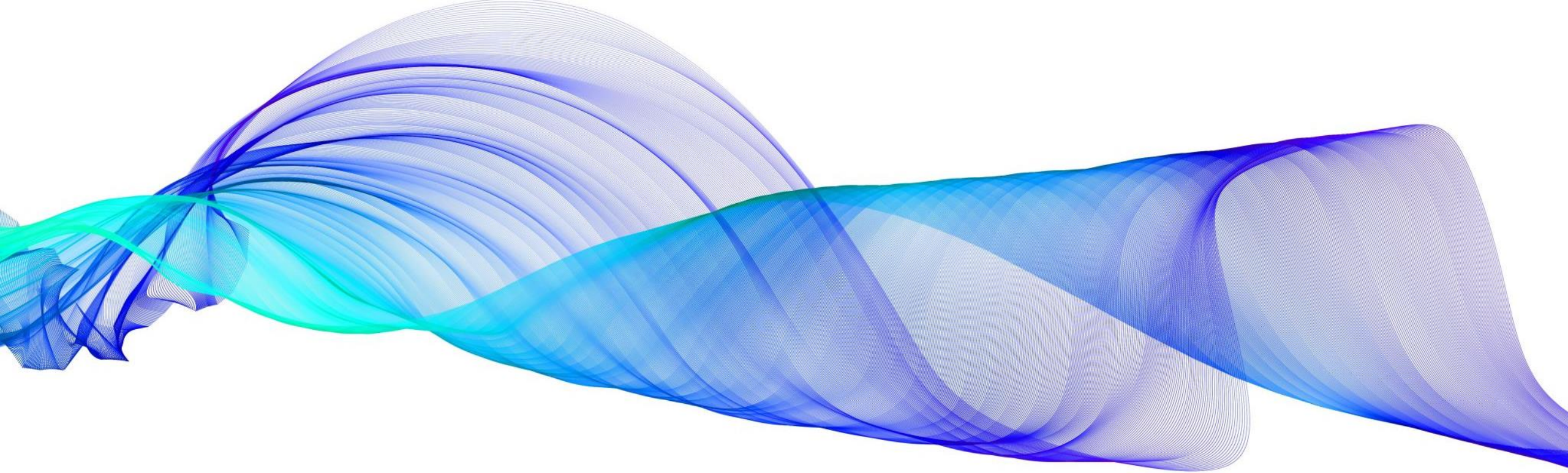
–1
1–3
6–12
24
48
72
168
last
Time (h)
Start HFJV



FIRST INTENTION HFJV FOR PERIVIABLE INFANTS

IOWA "KLEIN" APPROACH

- All periviable infants born at 22 – 23 weeks
  - intubated in the delivery room with either a 2.0 or 2.5 mm ETT
  - Within 10 min of life placed on first intention HFJV for lung protection to reduce the risks of volutrauma.
- Initial settings Rate=300 BPM with an inspiratory time of 0.02 s for an inspiratory to expiratory (I : E) ratio of 1 : 9. PEEP of 5cmH2O and adjust based on aeration & bag in surfactant

Elgin T et al. Current Opinion Peds 2022

IOWA CONTINUED

- $PaCO_2$ goal of 45–55 mmHg in the first 7 days of life
- If signs of PIE develop rate is lowered & a higher $PaCO_2$ is tolerated (60 mmHg).
- Initial PIP is started to elicit ‘good chest wall shake’ between 20 and 24 cmH_2O. Initially no conventional sigh breaths are added to minimize exposure to tidal volumes beyond those used with HFJV

Survival and short-term respiratory outcomes of <750 g infants initially intubated with 2.0 mm vs. 2.5 mm endotracheal tubes

Jennifer N. Berger[1]✉, Timothy G. Elgin[2], John M. Dagle[2], Jonathan M. Klein[2] and Tarah T. Colaizy[2]

Table 4. Respiratory complications.

	All $n = 147$	2.0 ETT $n = 69$	2.5 ETT $n = 78$	*p*-value
Pneumothorax, *n*, (%) $n = 141$	14/141 (11)	6/67 (9)	8/74 (11)	0.9443
Chest tube, *n*, (%)	8/14 (57)	4/6 (67)	4/8 (50)	0.5921
Pulmonary interstitial emphysema (PIE), *n*, (%) $n = 141$	18/141 (13)	9/67 (13)	9/74 (12)	0.8214
Pulmonary hemorrhage, *n* (%)	6/141 (4)	4/67 (6)	2/74 (3)	0.4235
Pneumonia, *n*, (%)	31/139 (22)	17/64 (27)	14/75 (19)	0.2650
BPD among survivors	121/121 (100)	52/52 (100)	68/68 (100)	1
BPD classification, *n*, (%)				Unadjusted $p = 0.0196$ Adjusted for gestational age $p = 0.2549$
Grade I	28 (23)	6 (12)	22 (32)	
Grade II	77 (64)	40 (77)	37 (54)	
Grade III	15 (13)	6 (12)	9 (13)	
$n = 120$				
Tracheostomy, *n*, (%)	4 (3)	2 (3)	2 (3)	1.0
Airway anomaly or stenosis, *n*, (%), $n = 127$	4/127 (3)	2/56 (4)	2/71 (3)	1.0

- Retrospective observational cohort
  - < 750g
  - Survival to discharge was similar 77%, 53/69 and 87%, 68/78 (p = 0.09).
  - Adjusted for GA, there were no significant differences in ventilator days (p = 0.7338) or Grade 3 BPD.

Berger et al Journal of Perinatol 2022

CONCLUSIONS

- There is a time and a place for high frequency ventilation
- In the presence of an air leak syndrome use of HFJV allows for lower MAP & may induce faster healing
- In optimizing outcomes for our smallest babies, HFJV may be an important device in our toolkit