Volume Targeted Ventilation in Preterm Infants

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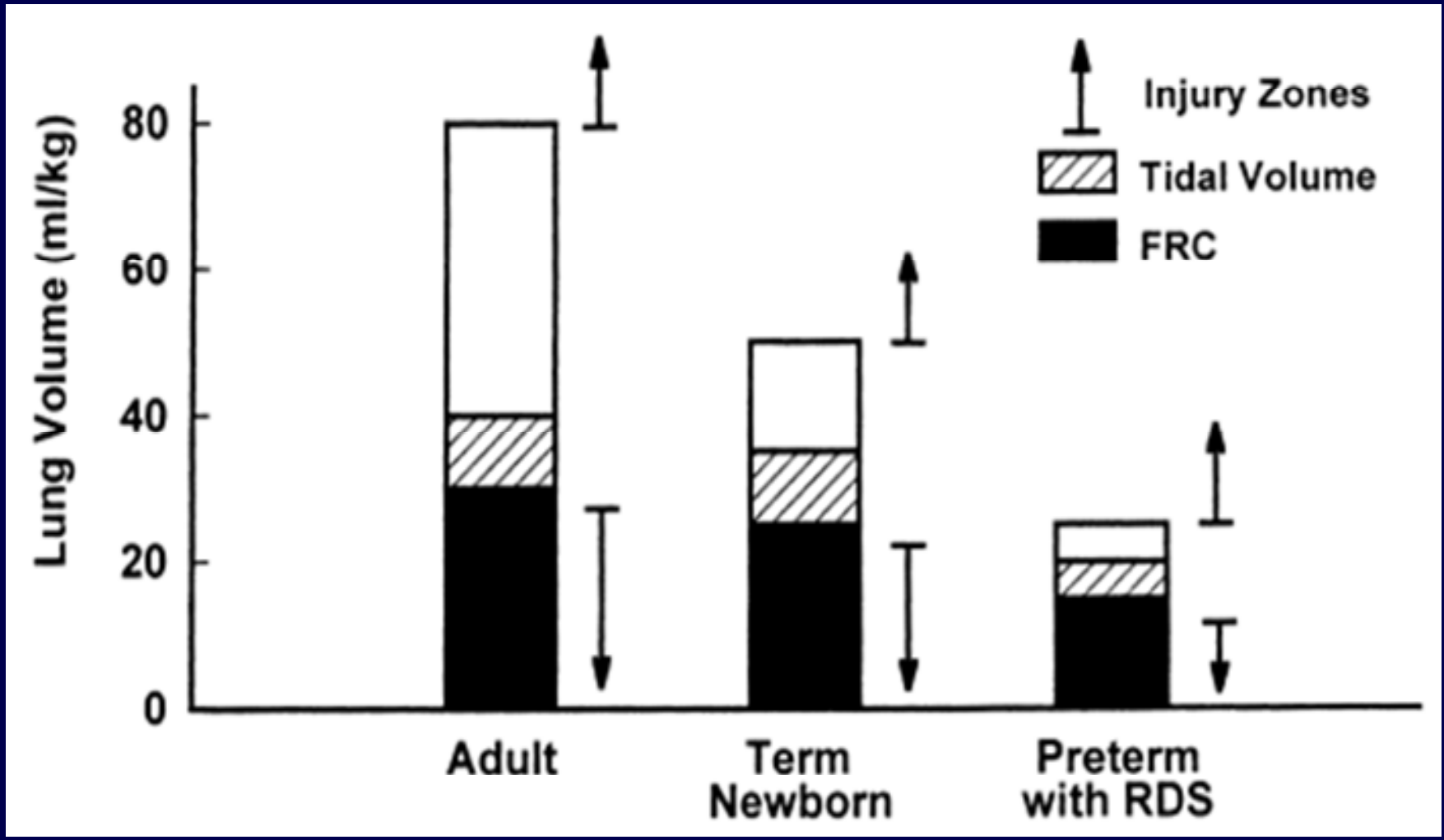
Susceptibility to volume induced lung injury in the preterm infant



from Jobe and Ikegami, Ear Hum Dev 1998

Prevention of ventilator induced lung injury

- Avoidance of volutrauma
  - Avoid excessive V_T ←
    - Limit ΔPressure (PIP – PEEP)
  - Avoid excessive lung volume
    - High PEEP, gas trapping
- Maintenance of lung volume
  - Apply sufficient PEEP
  - Maintain sufficient V_T ←
  - Avoid collapse – recruitment cycles
- Can volume targeted ventilation help?

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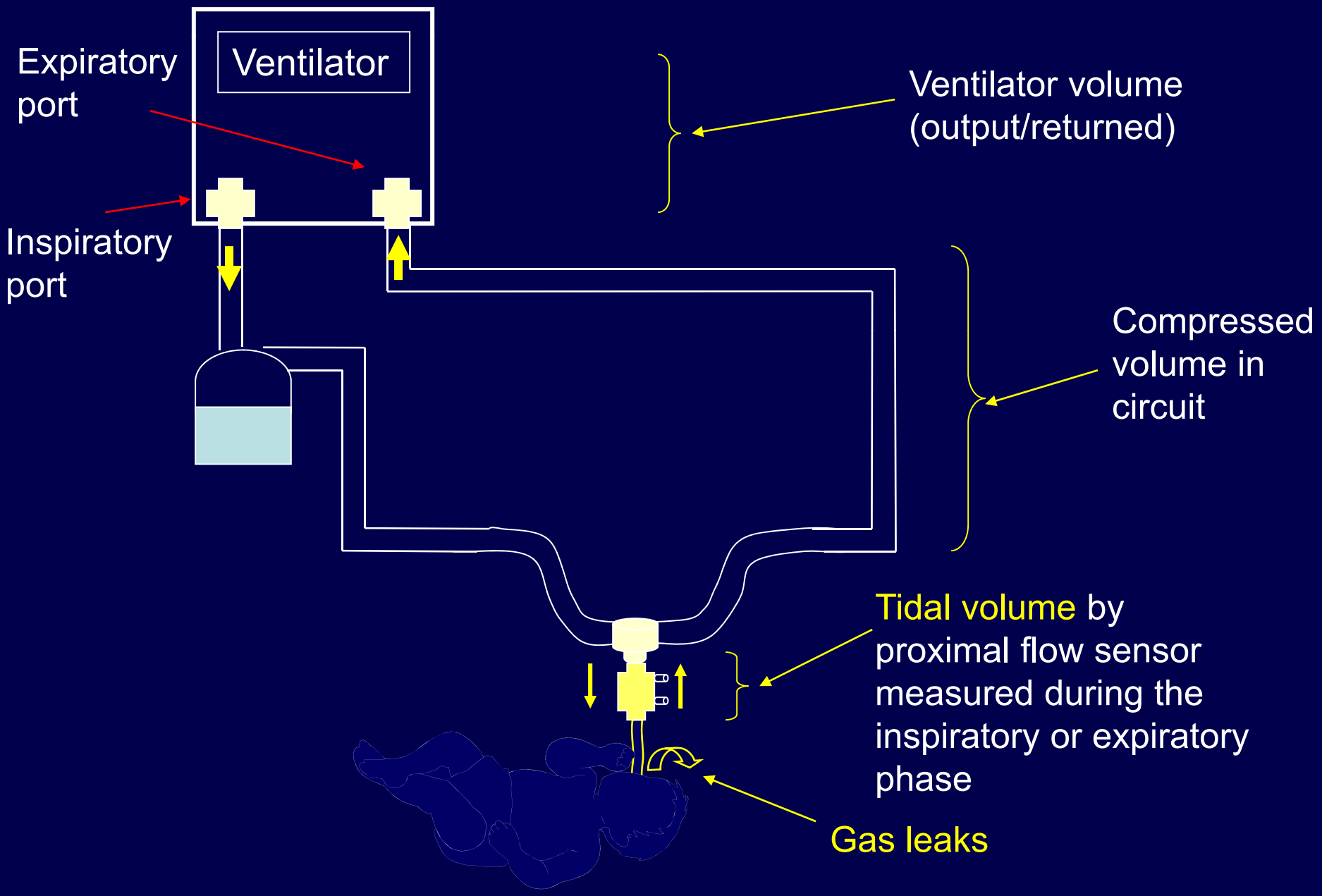
Methods and modalities of volume targeted ventilation

- Volume measurement
- PRVC: Pressure regulated volume control
- VC: Volume Controlled
- VG: Volume guarantee

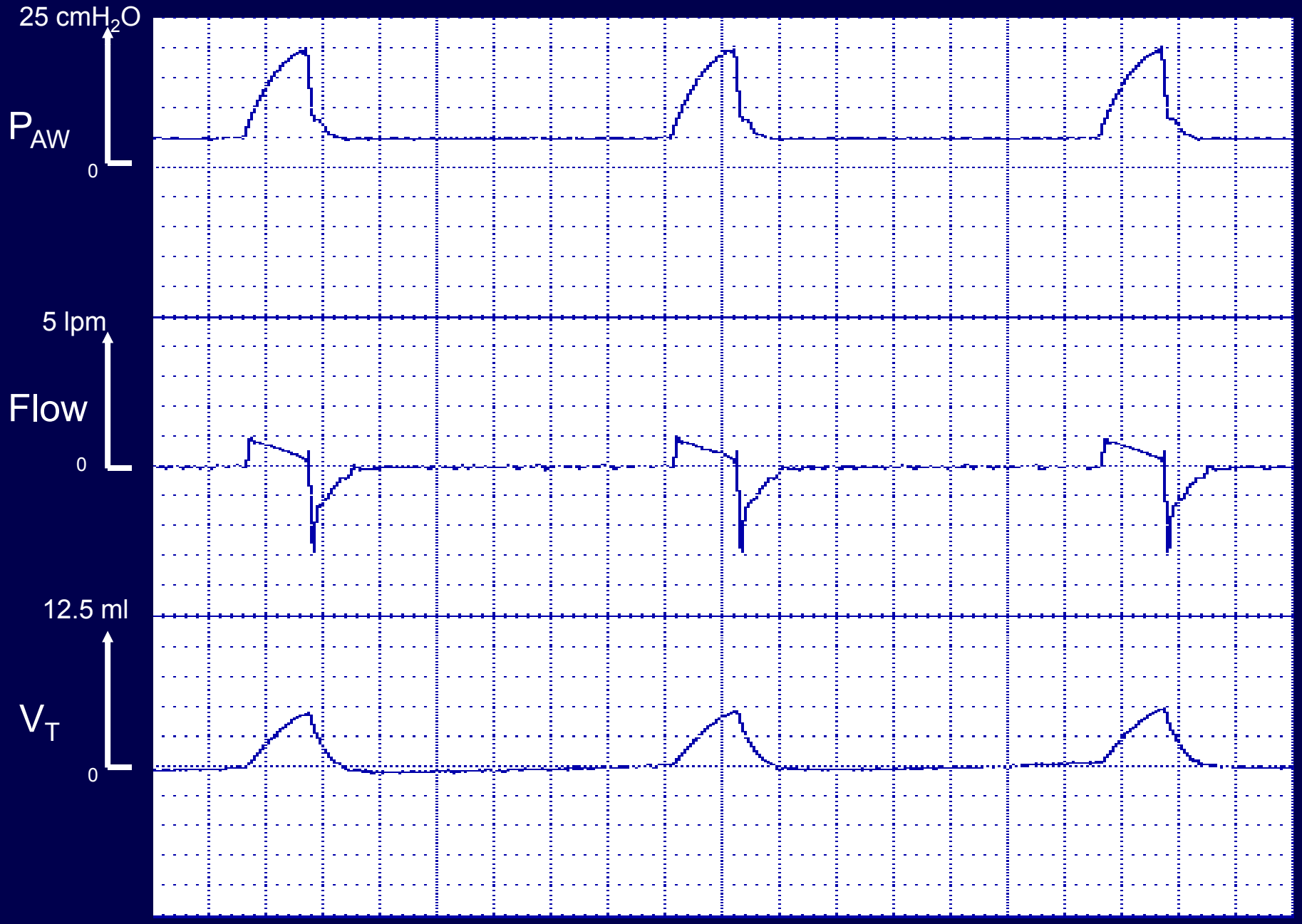
Volume measurement



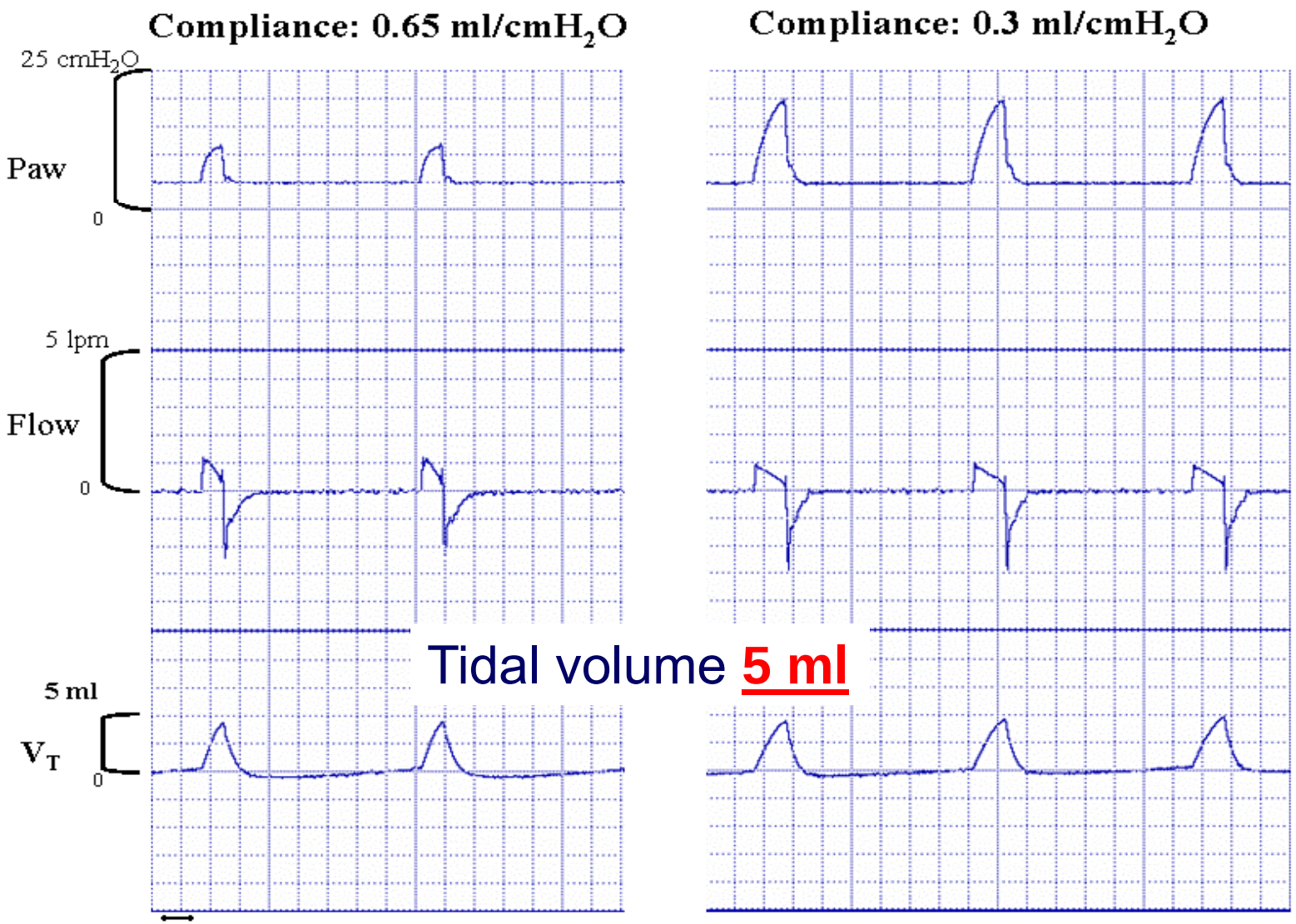
Volume Controlled

- Inspiratory phase continues until set volume is delivered
  - Peak pressure and Ti continue to increase
  - Set PIP and Ti become limits
- Volume delivered by ventilator (circuit volume+ tidal volume) during inspiratory phase
- Available in IMV, SIMV, and A/C modes

Volume controlled



Volume controlled



Tidal volume **5 ml**

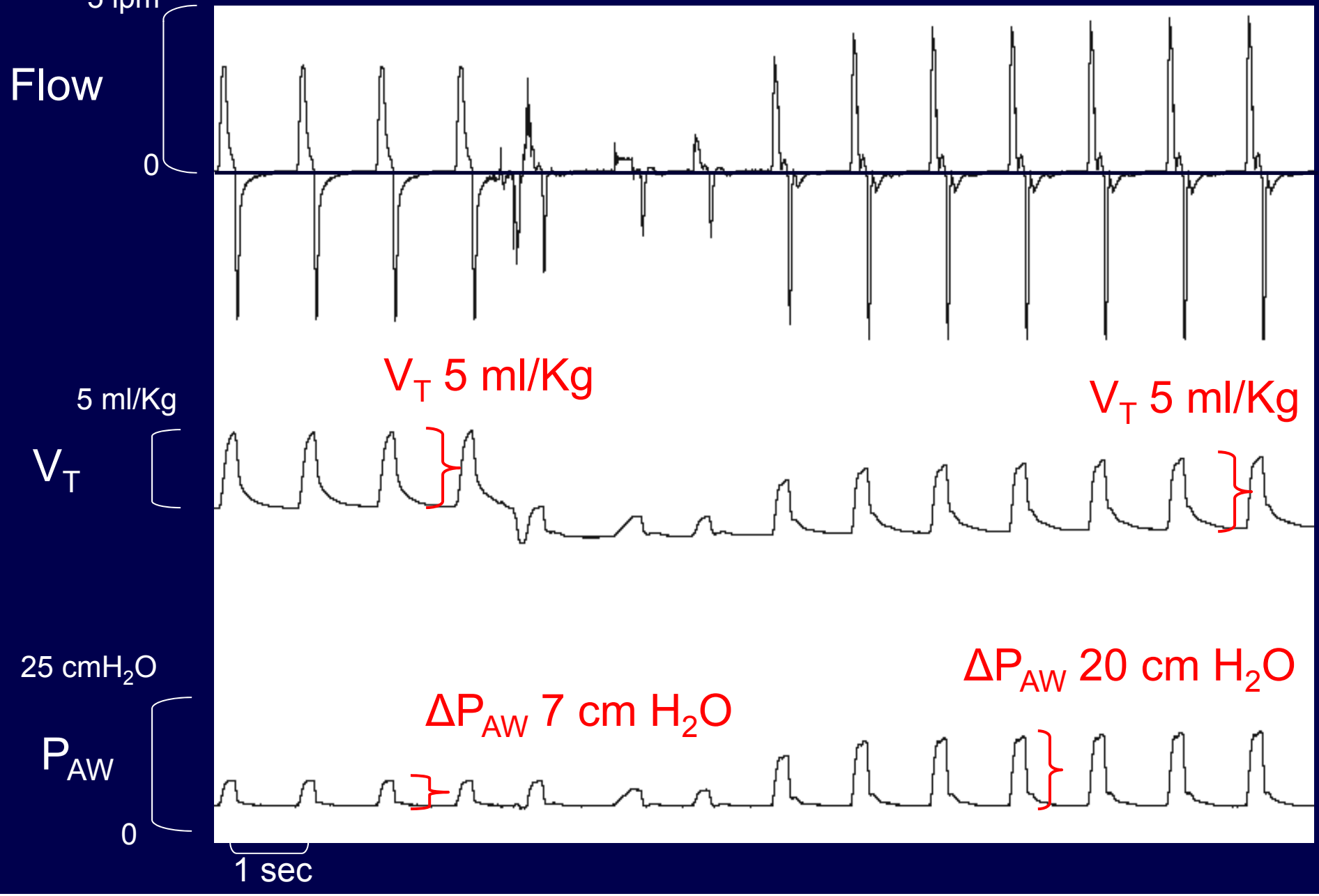
Set ventilator volume **12 ml**

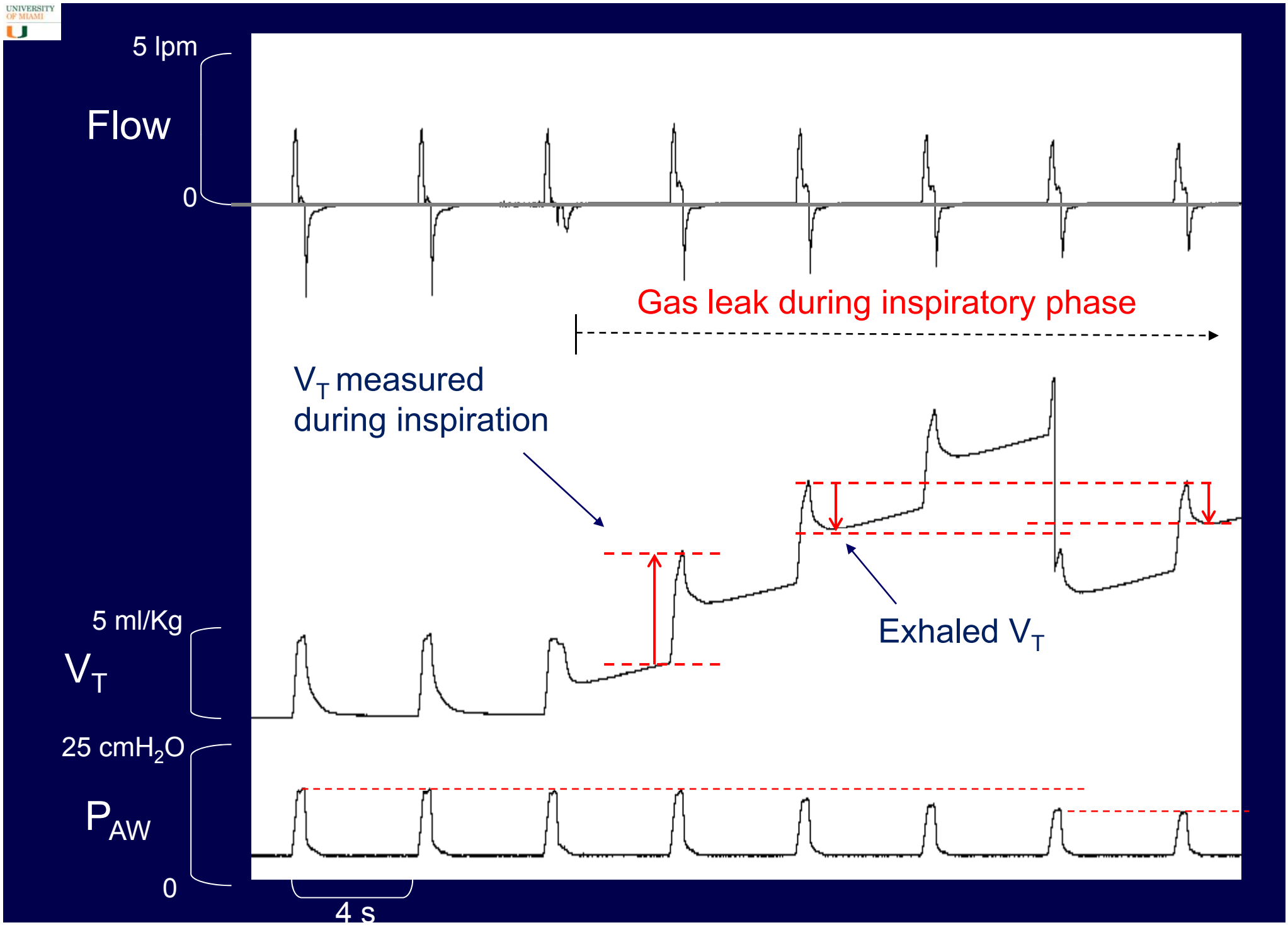
Set ventilator volume **16 ml**

Pressure Regulated Volume Controlled

- Time-cycled, pressure limited
- Peak pressure adjusted breath to breath
- Set PIP becomes peak pressure limit
- Inspiratory V_T compared to target V_T
- V_T measured at ventilator can be compensated for gas compressed in circuit
- Available only in A/C mode

PRVC


5 lpm
Flow
0
V_T 5 ml/Kg
V_T 5 ml/Kg
5 ml/Kg
V_T
25 cmH_2O
ΔP_{AW} 20 cm H_2O
ΔP_{AW} 7 cm H_2O
P_{AW}
0
1 sec


5 lpm
Flow
0
Gas leak during inspiratory phase
V_T measured
during inspiration
Exhaled V_T
5 ml/Kg
V_T
25 cmH_2O
P_{AW}
0
4 s

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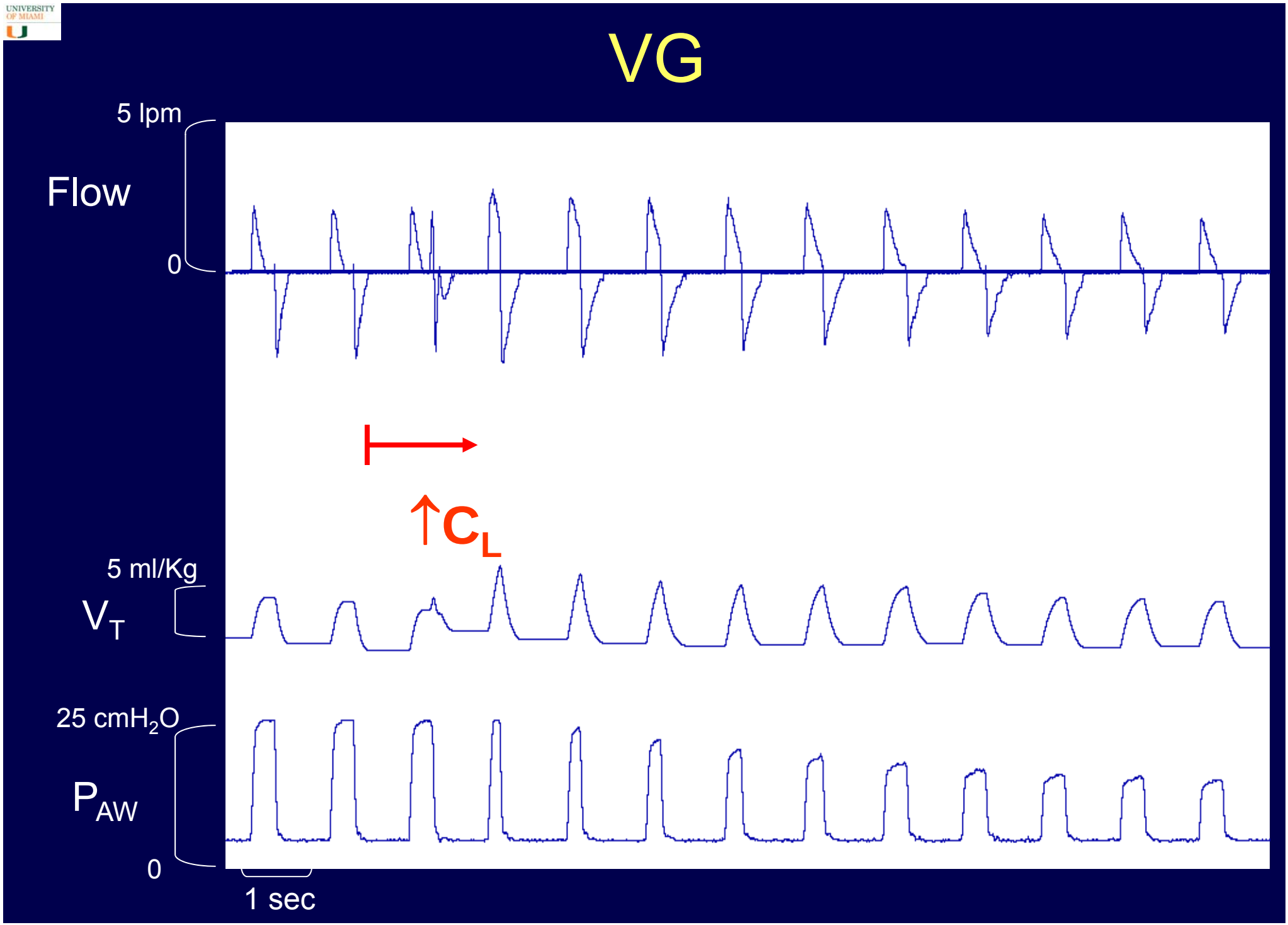
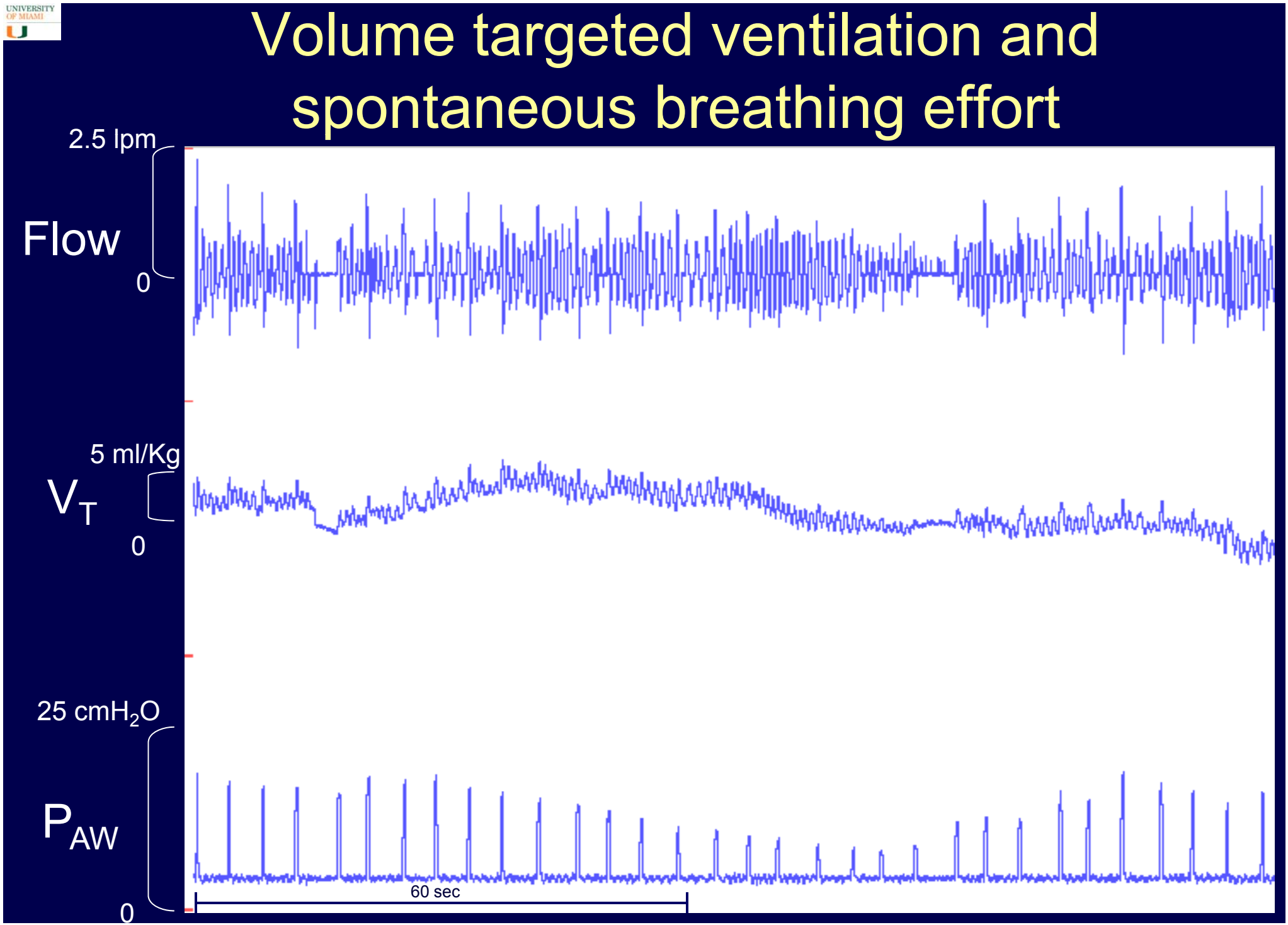
Volume Guarantee

- Time-cycled, pressure limited
- Peak pressure adjusted breath to breath
- Set PIP limits the peak pressure
- Exhaled V_T compared to target V_T
- Available in PSV, A/C, IMV and SIMV


VG
5 lpm
Flow
0
↑C_L
5 ml/Kg
V_T
25 cmH_2O
P_{AW}
0
1 sec

Volume targeted ventilation and spontaneous breathing effort



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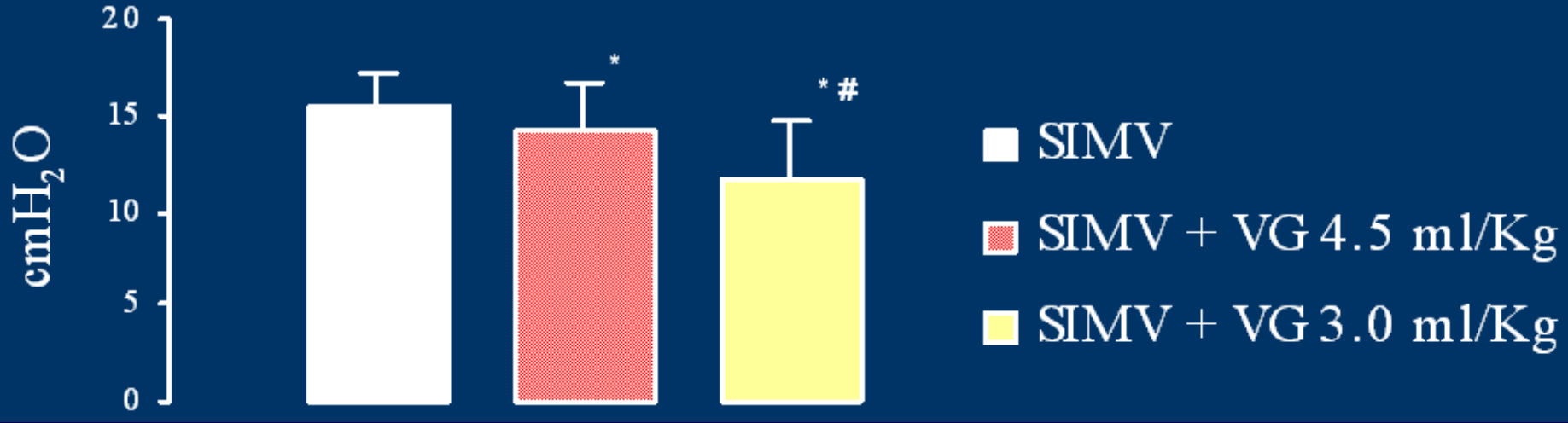
Effects of volume targeted ventilation

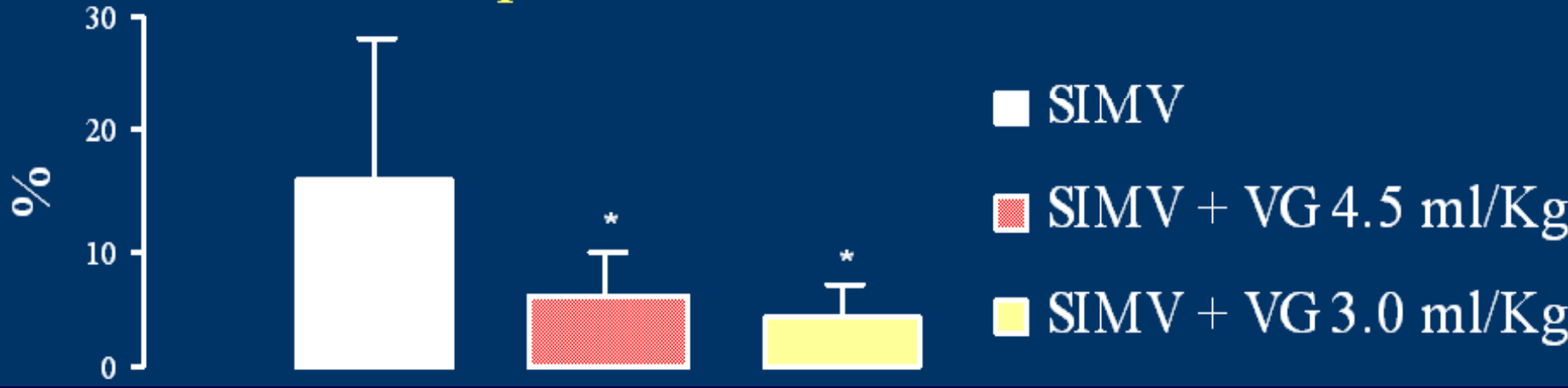
- Weaning of peak pressure
- Stability of tidal volume and gas exchange
- Inflammation
- Duration of ventilation
- BPD

Automatic weaning

Peak inspiratory pressure



Mechanical V_T > 7 ml/Kg



Herrera et al. Pediatrics 2002

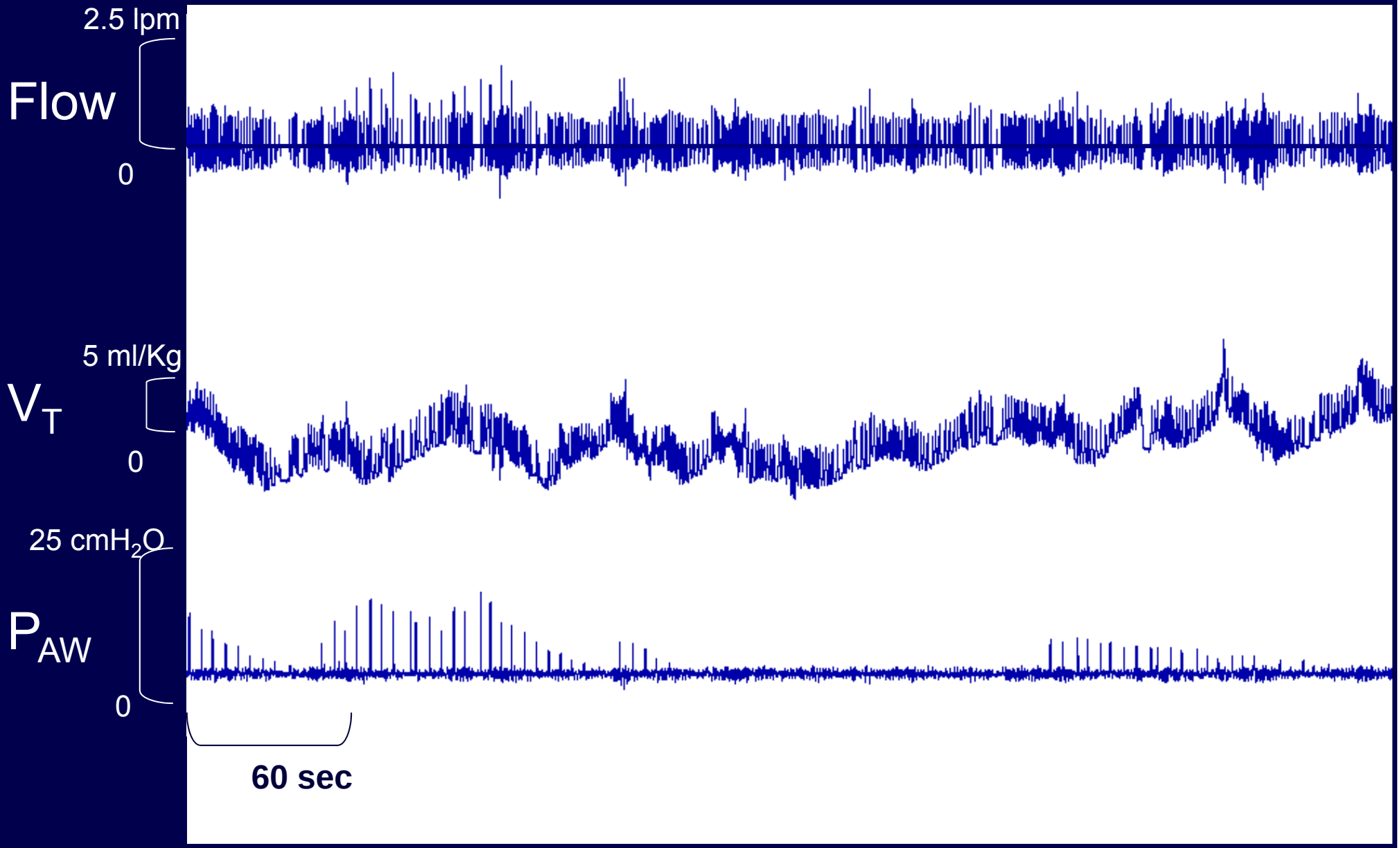
*: p<0.05 versus SIMV, #: p<0.05 versus SIMV+VG4.5

Automatic weaning

	SIMV	SIMV+VG 4.5	SIMV+VG 3.0
PIP (cmH_2O)	15.4 ± 1.7	14.2 ± 2.4	11.7 ± 2.9*†
MAP (cmH_2O)	5.3 ± 1.4	4.9 ± 1.3*	4.4 ± 0.53*†
$V_{T\ mech}$ (mL/kg)	5.9 ± 0.8	4.8 ± 0.4*	4.2 ± 0.6*†
$V_{T\ mech}$ > 7 mL/kg (%)	16 ± 12	6 ± 4*	4 ± 3*
$V_{T\ spont}$ (mL/kg)	2.5 ± 0.6	3.3 ± 0.7*	3.6 ± 0.5*
Mechanical rate (breaths/min)‡	16 ± 3	15 ± 3	12 ± 4*†
Spontaneous rate (breaths/min)	41 ± 15	46 ± 11*	51 ± 10*†
Total rate (breaths/min)	57 ± 12	61 ± 9*	63 ± 8*†
FIO_2	0.23 ± 0.024	0.23 ± 0.023	0.23 ± 0.018
SPO_2 (%)	94 ± 2.1	94 ± 2.4	95 ± 1.5
$TcPCO_2$ (mmHg)	46.8 ± 11.5	48.2 ± 13.4	52.0 ± 11.0
Coeff. of var. V_T (%):	27±7	31±7	41±7

Herrera et al. Pediatrics 2002

Is V_T 3 ml/Kg too low?



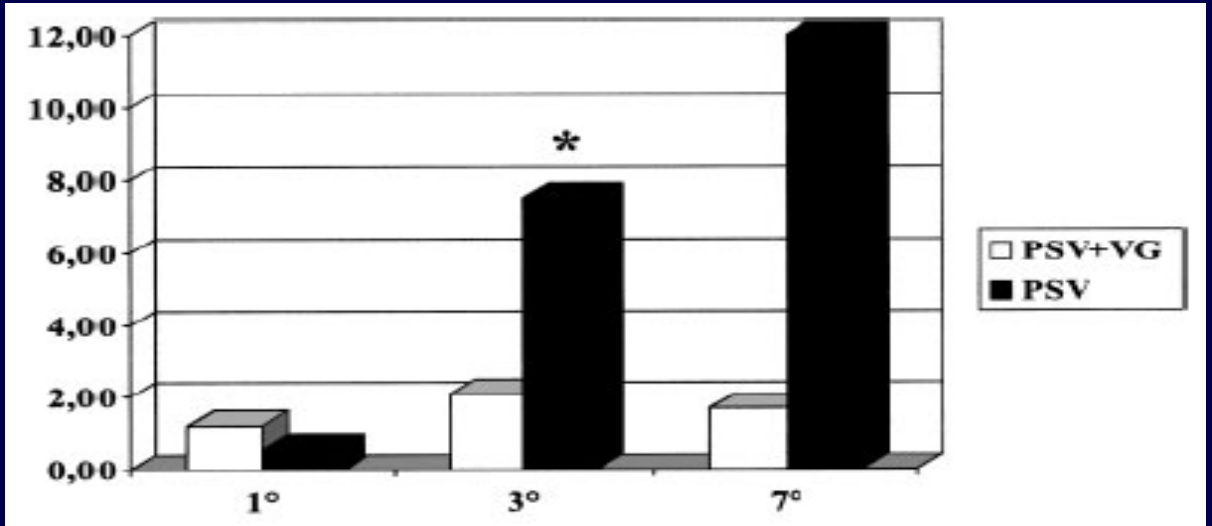
Stability of Tidal Volume and Incidence of Hypocarbia

Keszler et al. Ped Pulmonol 2004

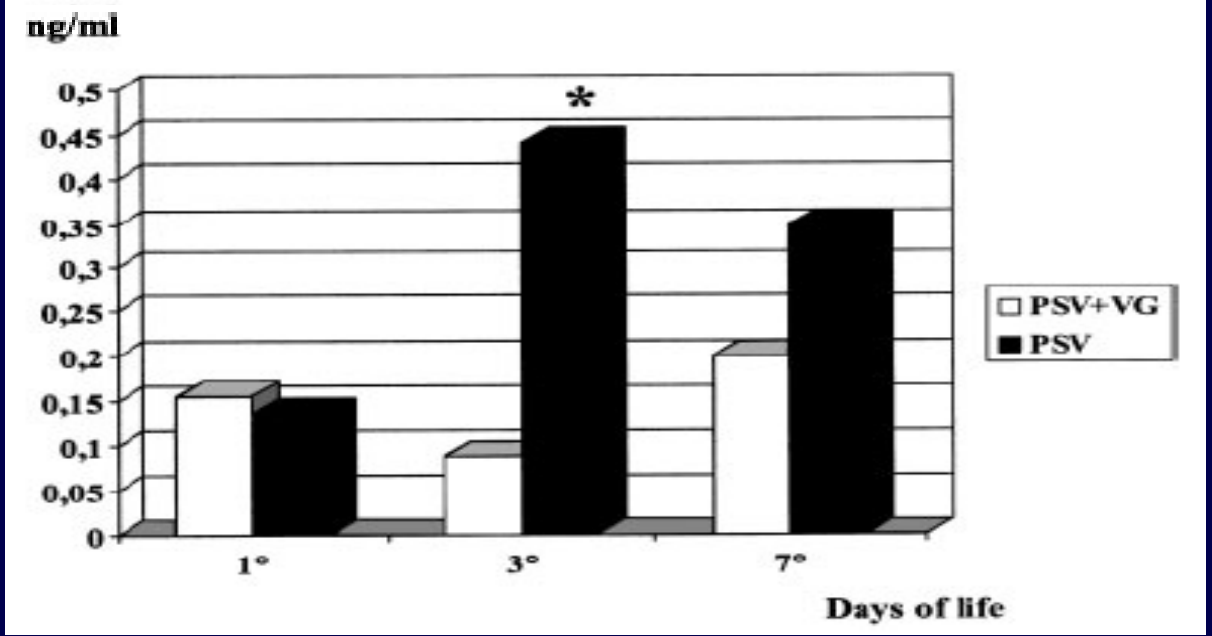
	A/C	A/C + VG (target V_T 5.0 ml)
V_T < 4 ml/Kg	35%	21%
V_T > 6 ml/Kg	25%	15%
(% of breaths)		
$PaCO_2$ < 35 mmHg	36%	20%
$PaCO_2$ > 45 mmHg	17%	19%
(% of samples)		

PSV vs. PSV**+VG** @**5.0** in RDS
Inflammatory mediators on d 1-3-7 (n=53)

IL-8



IL-6

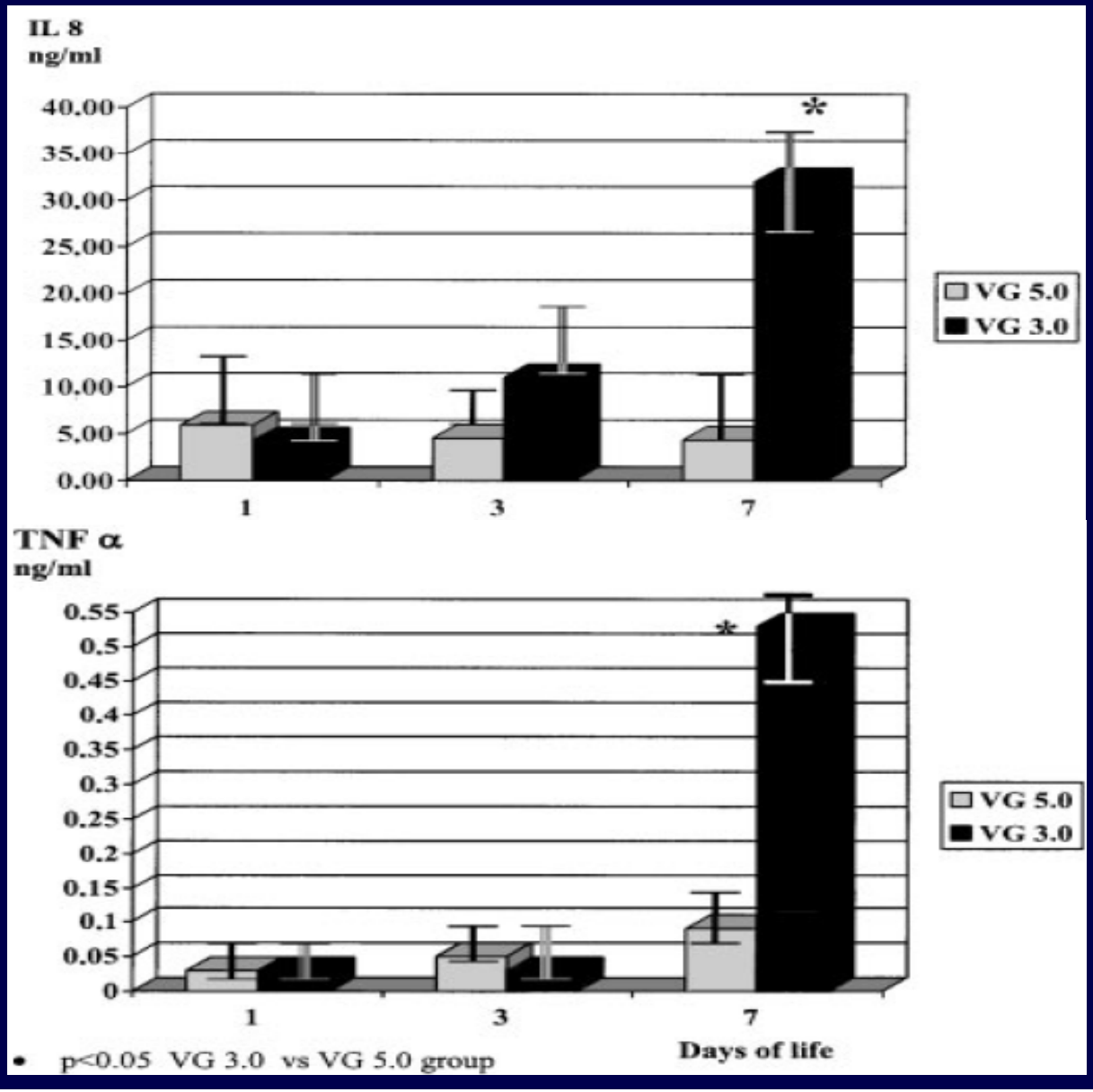


Lista et al.
Ped Pulmonol 2004

A/C**+VG 5.0** vs. A/C**+VG 3.0** in RDS
Inflammatory mediators on d 1-3-7 (n=30)

IL-8

TNFα



Lista et al.
Ped Pulmonol 2006

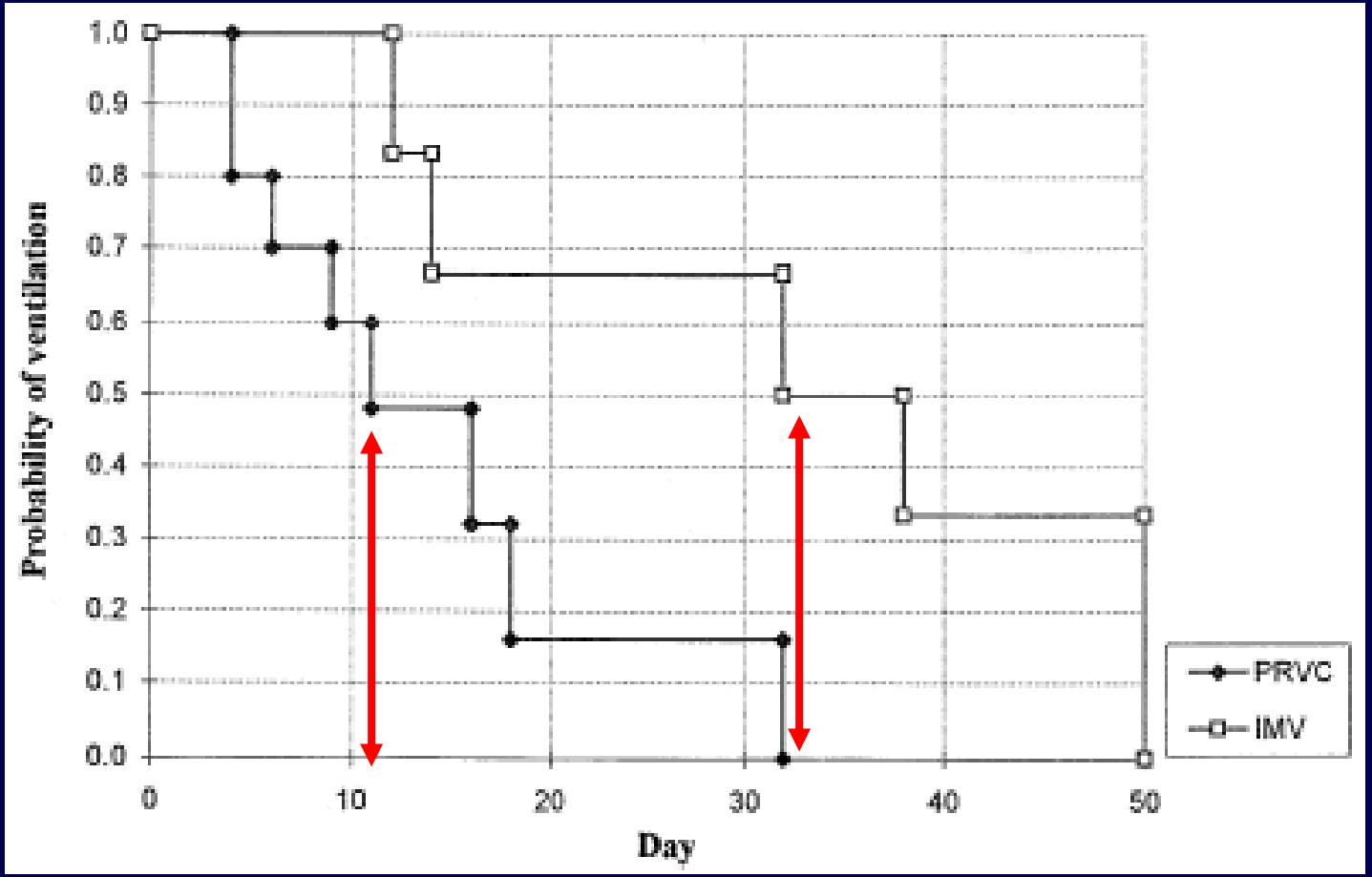
VC vs. TCPL in RDS

		VC	TCPL
Sinha 1997	50 infants BW ≥1200g VIP Bird	MV days 5 BPD 1/25	7 * 5/25
Singh 2006	109 infants BW 600-1500g VIP Gold	MV days 11 BPD 28%	14 33%

PRVC vs. IMV in RDS
Piotrowski et al. Int Care Med 1997

		PRVC (in A/C)	IMV
Piotrowski	MV days	8	8
57 infants	BPD	6/27	6/31
BW 600-1200g			
Servo 300			

PRVC vs. IMV
Duration of Ventilation in BW<1000 g



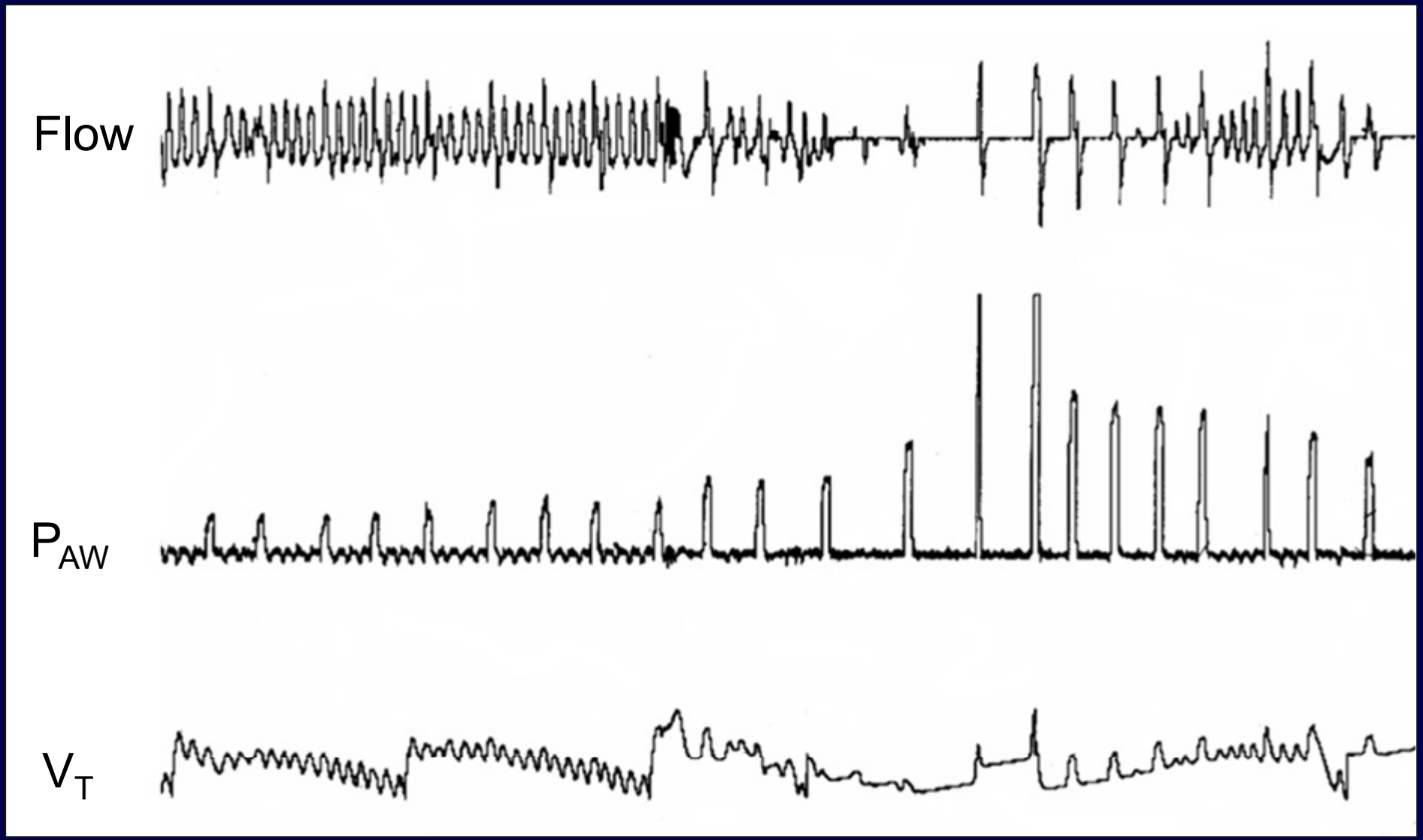
Piotrowski et al. Int Care Med 1997

PRVC vs. SIMV

D'Angio et al. Arch Pediatr Adolesc Med 2005

		PRVC (in A/C)	**SI**MV
212 infants BW 500-1249g Servo 300	Age extub.	33d	24d
	BPD	35%	29%

Can VTV prevent acute hypoventilation and hypoxemia?



Volume Targeted-SIMV on Spontaneous Episodes of Hypoxemia in Preterm Infants

Polimeni et al. Biol Neonate 2006

Crossover trial SIMV vs. VT-SIMV

32 infants with frequent episodes of hypoxemia

GA 25 ± 1 wks, Age 38 ± 17 d

Initial phase (n=12)

SIMV vs. VG-SIMV with V_T @ 4.5 ml/Kg

- No effect on hypoxemia episodes

Second phase (n=20)

SIMV vs. VG-SIMV with V_T @ 6.0 ml/Kg

SIMV vs. VG-SIMV @ 6.0 ml/Kg

	SIMV	VG-SIMV
PIP (cmH_2O)	18±2	23±3 *
V_T mech (ml/Kg)	4.9±1.0	5.5±0.4 *
V_T mech ≤ 3 ml/Kg (% of breaths)	22±6	14±7 *

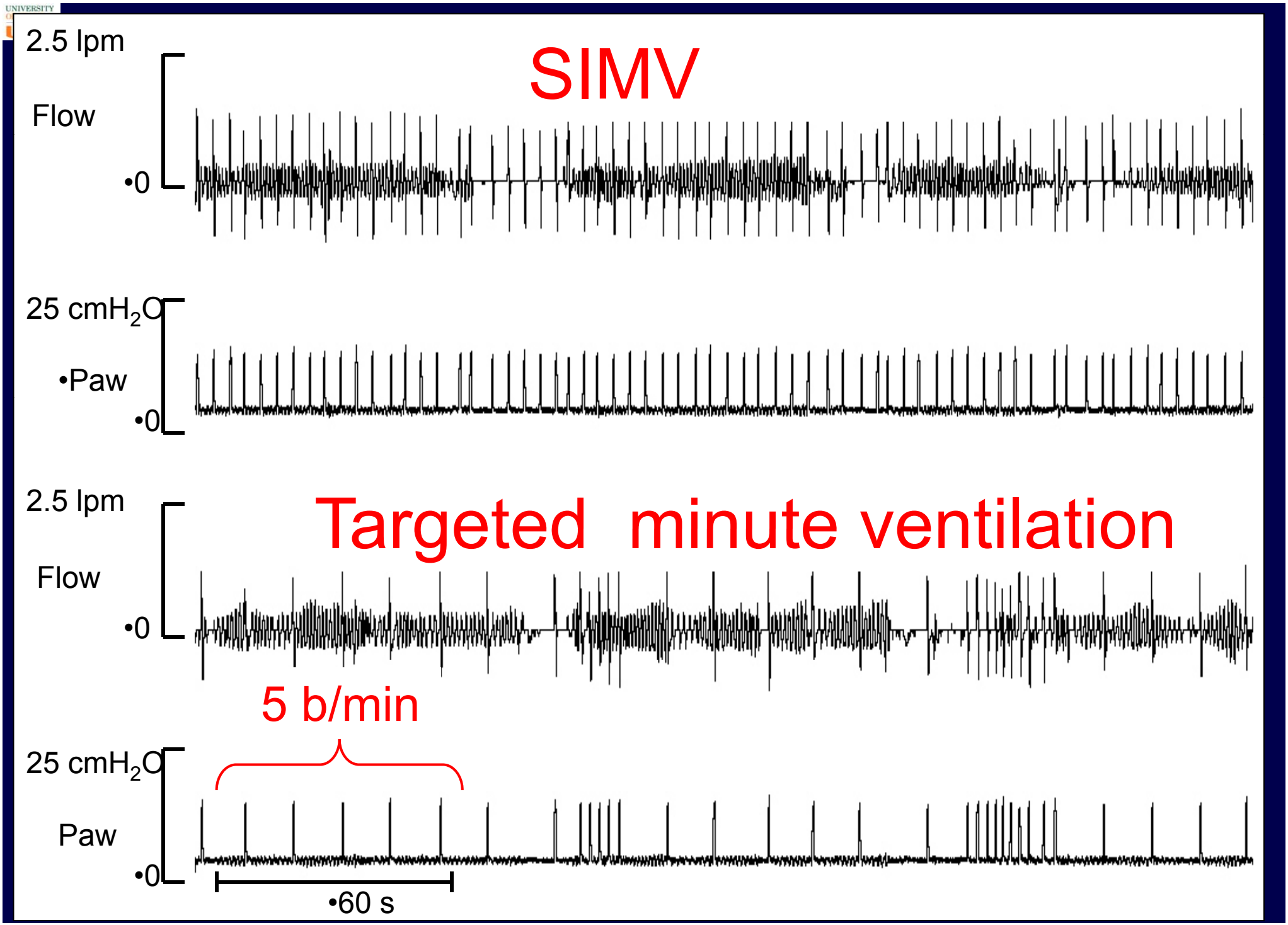
SIMV vs. VG-SIMV @ 6.0 ml/Kg

	SIMV	VT-SIMV 6.0
Episodes with SpO_2 <88% (n = 20 infants)		
Frequency, episodes/h	14.6 ± 6.8	14.5 ± 8.8
Episode duration, s	46.3 ± 22 →	35.5 ± 13.8*
Mean SpO_2 during episode, %	81.8 ± 2.4	82.7 ± 1.6*
Time with SpO_2 <88%, % of total time	19.9 ± 10.2	16.6 ± 10.7
Episodes with SpO_2 <75% (n = 15/20 infants)		
Frequency, episodes/h	3.4 ± 4.1	2.5 ± 3.1
Episode duration, s	30.2 ± 29	16 ± 6.5
Mean SpO_2 during episode, %	70 (33–72)	71 (31.5–73)
Time with SpO_2 < 75%, % of total time	2.7 ± 3.3 →	1.3 ± 1.7*
Mean FiO_2	0.41 ± 0.08	0.40 ± 0.07
Mean SpO_2, %	91.3 ± 2.3	92.1 ± 2.2

* $p < 0.05$ vs. SIMV.

Polimeni et al. Biol Neonate 2006

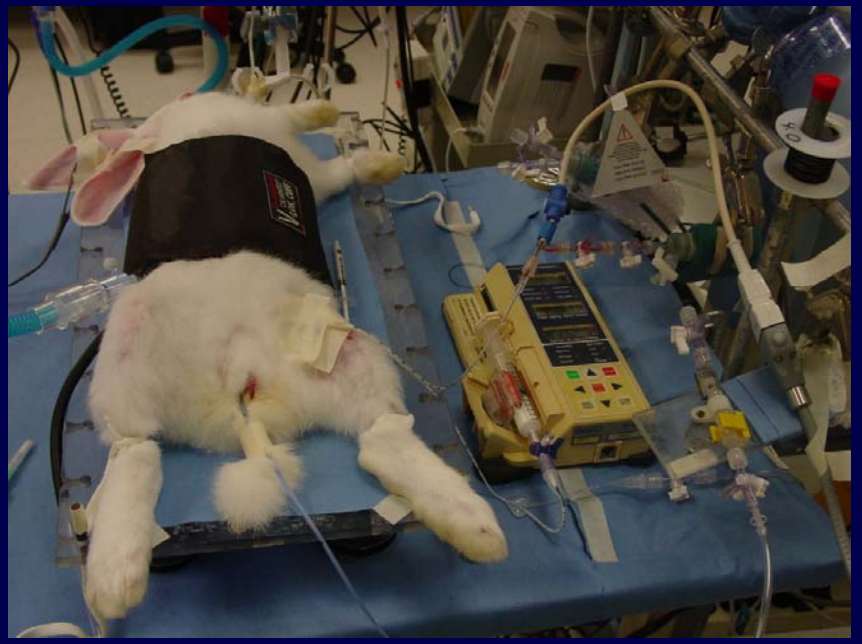
Combined
Targeted minute ventilation
(automatic adjustment of rate)
and
Volume targeted ventilation
(automatic adjustment of PIP)


2.5 lpm
Flow
•0
SIMV
25 cmH2O
•Paw
•0
2.5 lpm
Flow
•0
Targeted minute ventilation
5 b/min
25 cmH2O
Paw
•0
•60 s

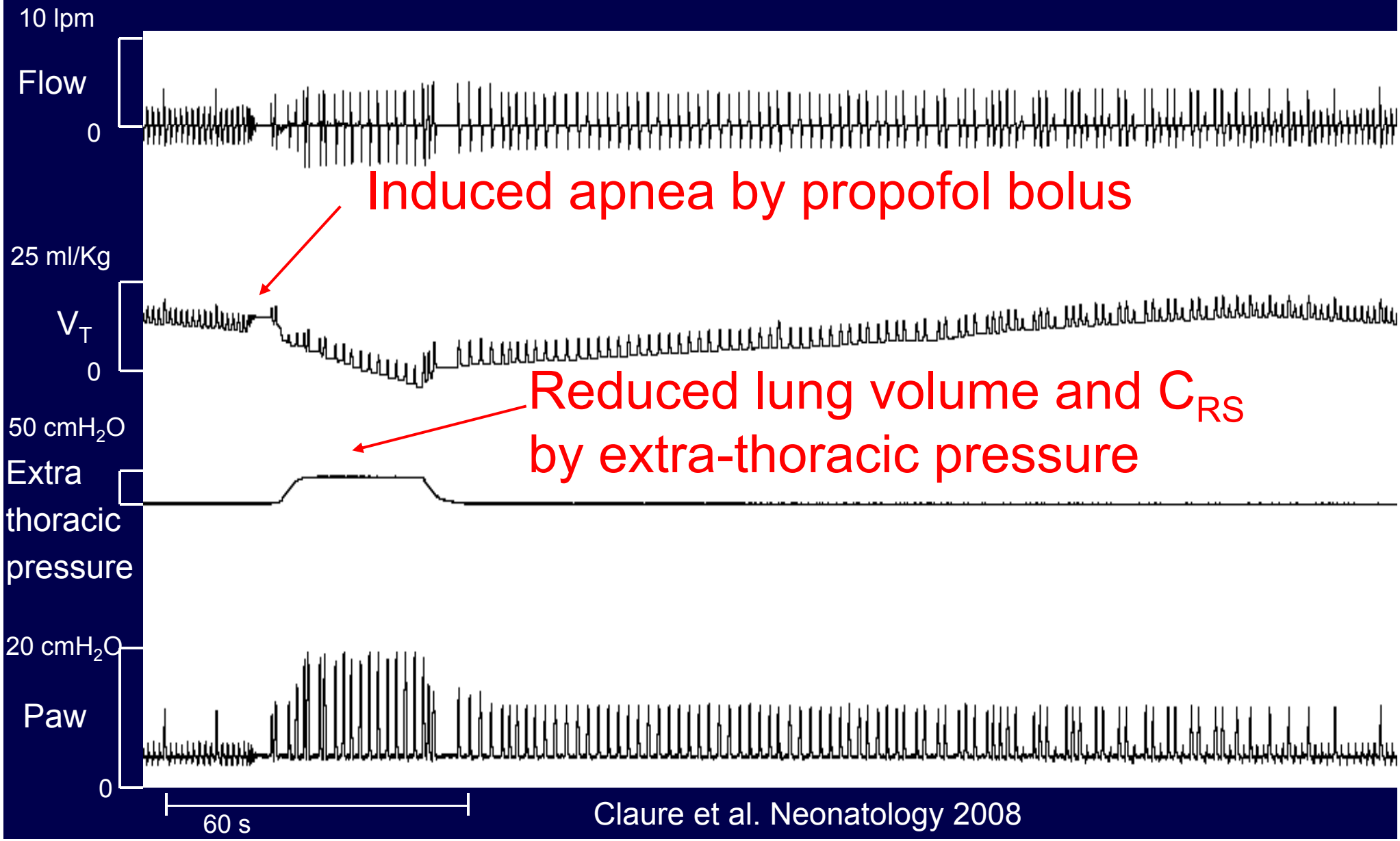
Experimental Setup

- Apnea induced by propofol bolus
- Reduction in lung volume and C_{RS} by cuff around chest
- PaO_2 and $PaCO_2$ by indwelling electrode in femoral artery

- Random sequence:
  - Conventional SIMV
  - Targeted V_T
  - Targeted V'_E
  - Targeted $V'_E + V_T$

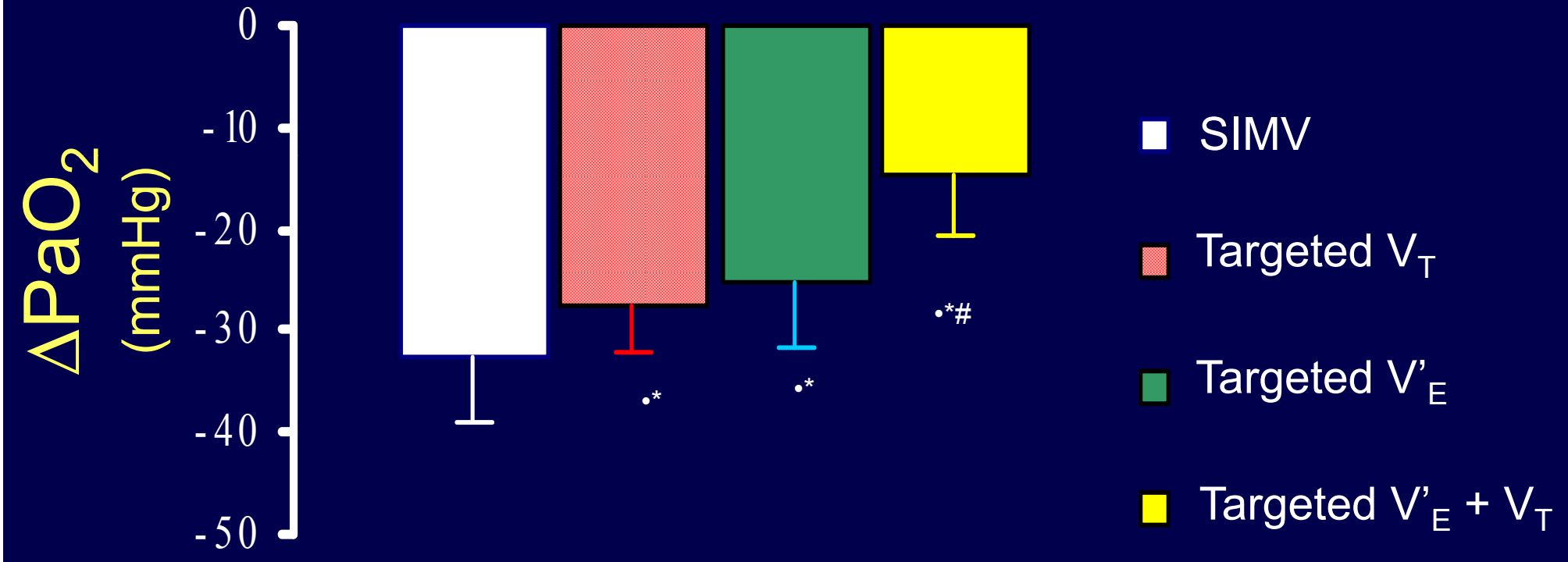


Targeted V'_E + targeted V_T during apnea with reduced volume and C_{RS}



Claure et al. Neonatology 2008

Decrease in PaO_2 with induced apnea + reduced lung volume and C_{RS}



*: $p < 0.05$ vs SIMV

#: $p < 0.05$ vs Targeted V_T

Claure et al. Neonatology 2008

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Volume targeted ventilation

- Can achieve weaning of peak pressure
- Avoids extremes of V_T
- Prevent hypocapnia
  - A too low target V_T can lead to higher $PaCO_2$
- Attenuates acute hypoventilation and hypoxemia
  - Requires a higher target V_T
- Shorter duration of ventilation
- No effect on BPD
- Can VG attenuate inflammation?
- What is the most effective range of V_T?

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Questions and Considerations

- Was VTV introduced too late?
- Can volume targeting/limiting be done manually?
- Are there differences between modes of VTV?
  - Some other VTV modes are used w/o physiologic or clinical data
- Adequately safe, if used appropriately
- Optimal and most effective V_T for different phases of respiratory failure?
- Trials should focus on or stratify smaller infants