Newer modes of ventilation: Hope or Hype!

Dr Anu Sachdeva

dranuthukral@gmail.com

AIIMS, New Delhi

Declaration

- No conflicts of interest
- No AI tool [chat GPT, Google Bard, chat sonic, mid-journey etc.] for the presentation

Dr. Sydney S Gellis

As far as I am concerned, the whole area of ventilation of a preterm infant is a chaos.

"Claims and counterclaims about the best and least harmful method make me light-headed."

Learning Objectives

- Basics of ventilation
  - *A brief intro: phase/ control*
- Conventional neonatal ventilation
  - *Issues of asynchrony*
- Newer modes
  - *SIMV, A/C, PSV…*
- Evidence
  - *Should we change the practice?*

Basics of ventilation

Control Variables

- Ventilator controls/ Targets either
  - *Pressure*
  - *Volume*
  - *Flow*
  - *Newer generation control different modes at different times*

Phase variables

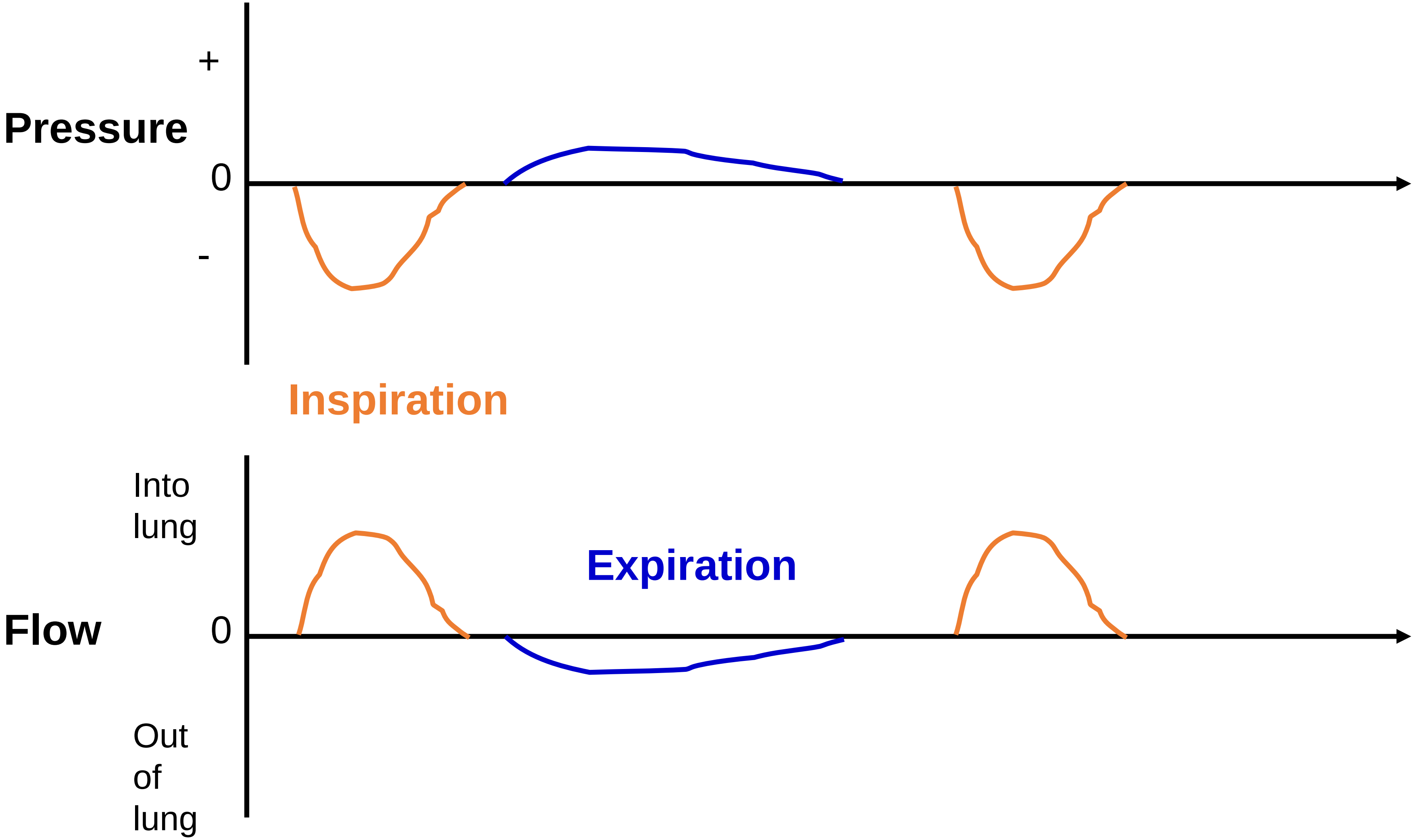
- Pressure, Volume and Flow can be used as phase variables to
  - Trigger
  - Limit
  - Cycle

Pressure Targeted
Volume Control
Hybrid Modes (PRVC/ VAPS/VG)

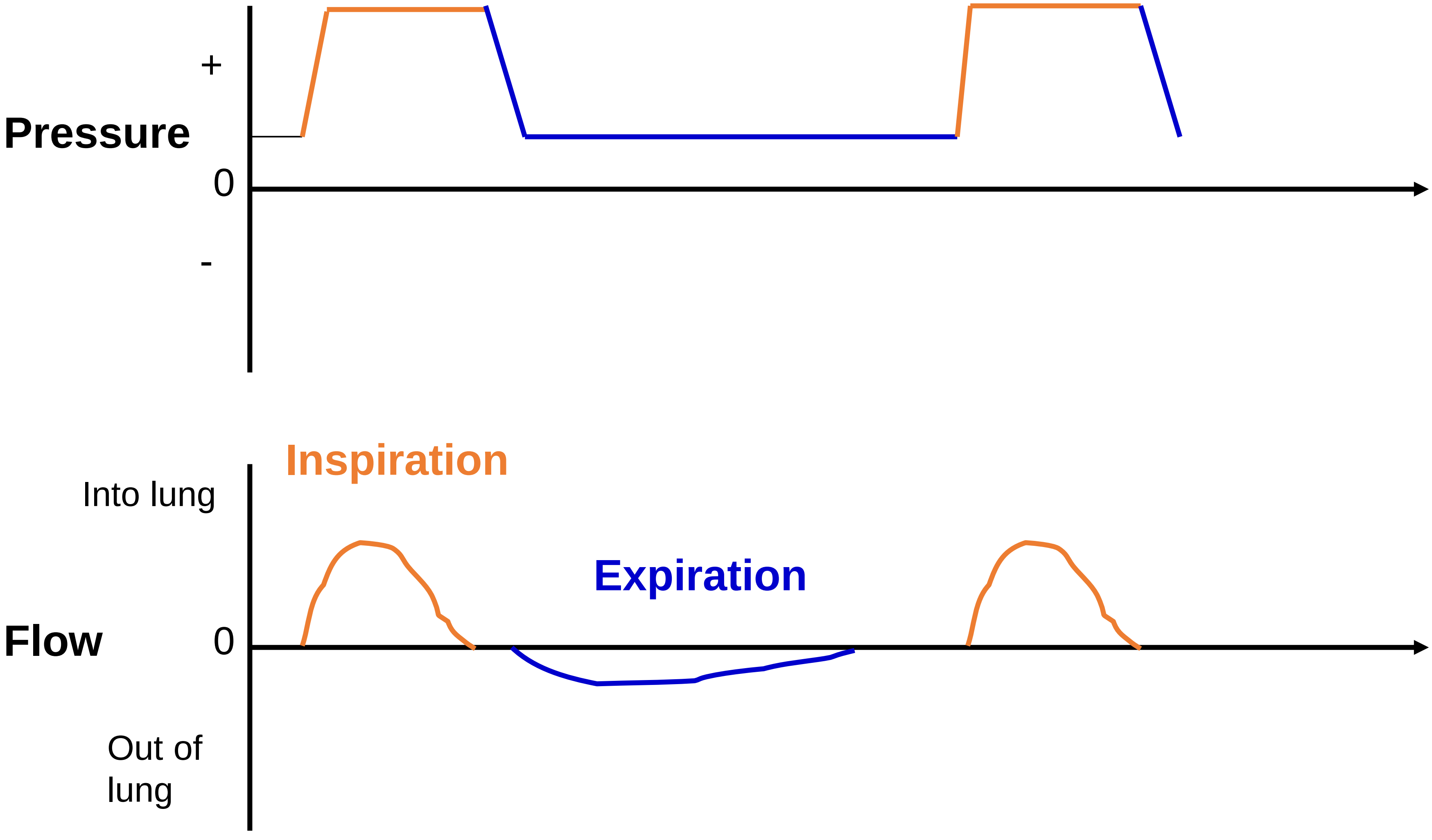
Making it a little complex…

- Graphs and terminologies!

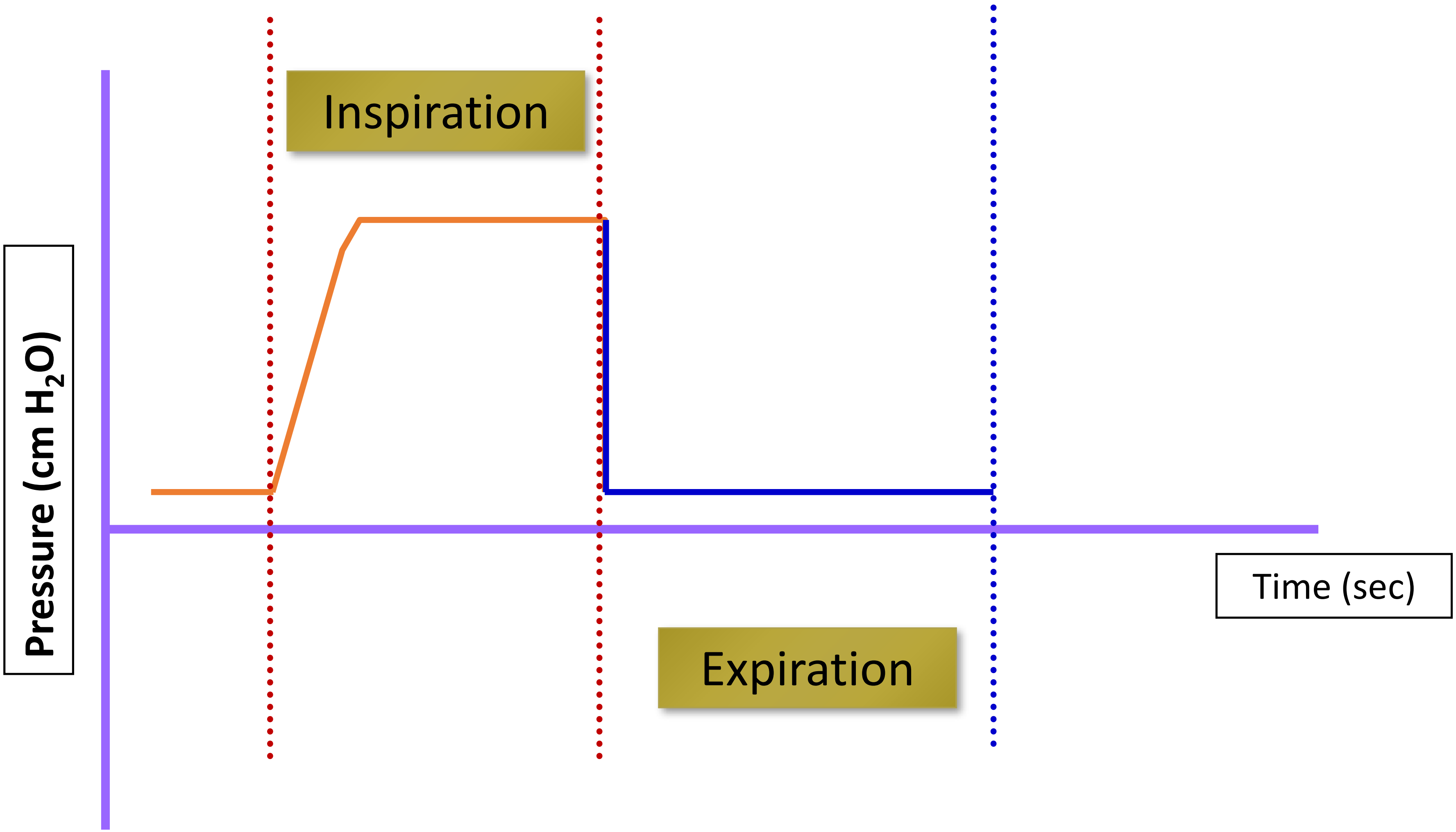
Spontaneous breathing



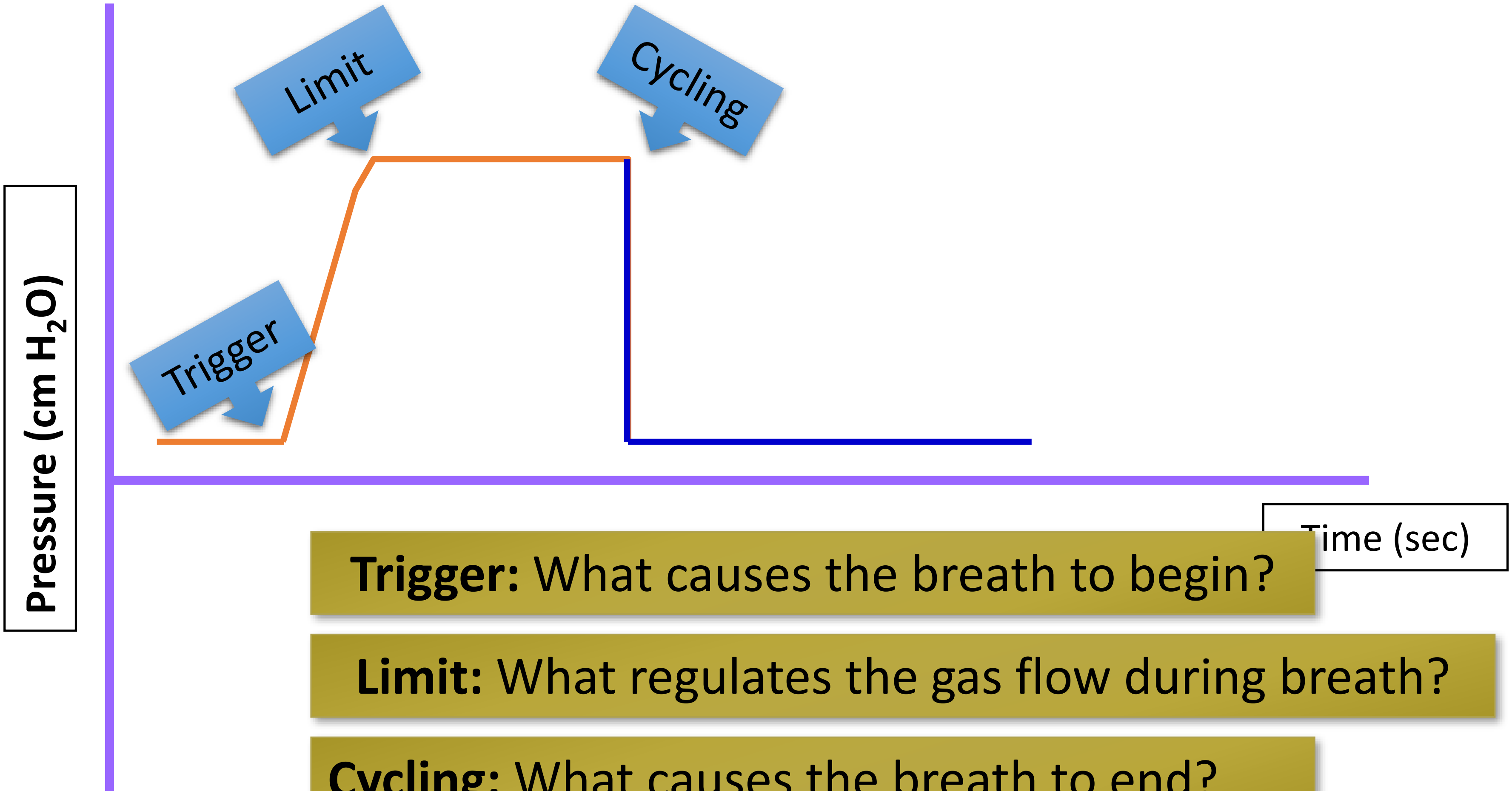
Ventilator breathing



Ventilator breath



Terminology



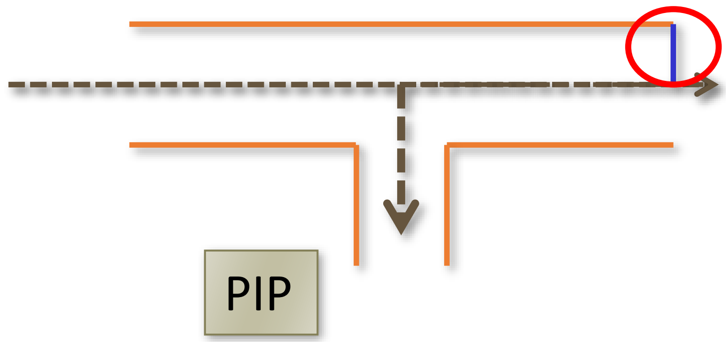
Trigger: What causes the breath to begin?

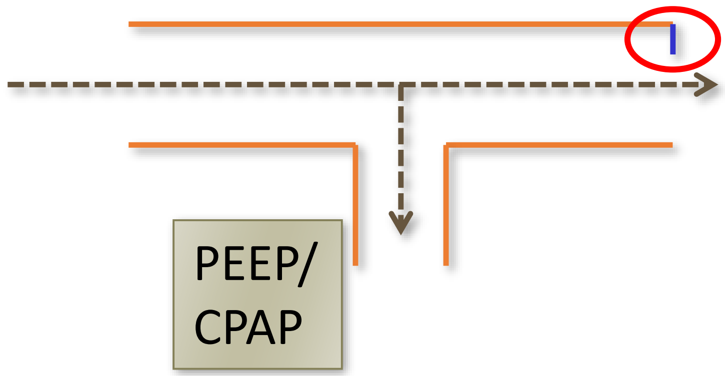
Limit: What regulates the gas flow during breath?

Cycling: What causes the breath to end?

Conventional neonatal ventilation

Conventional ventilator

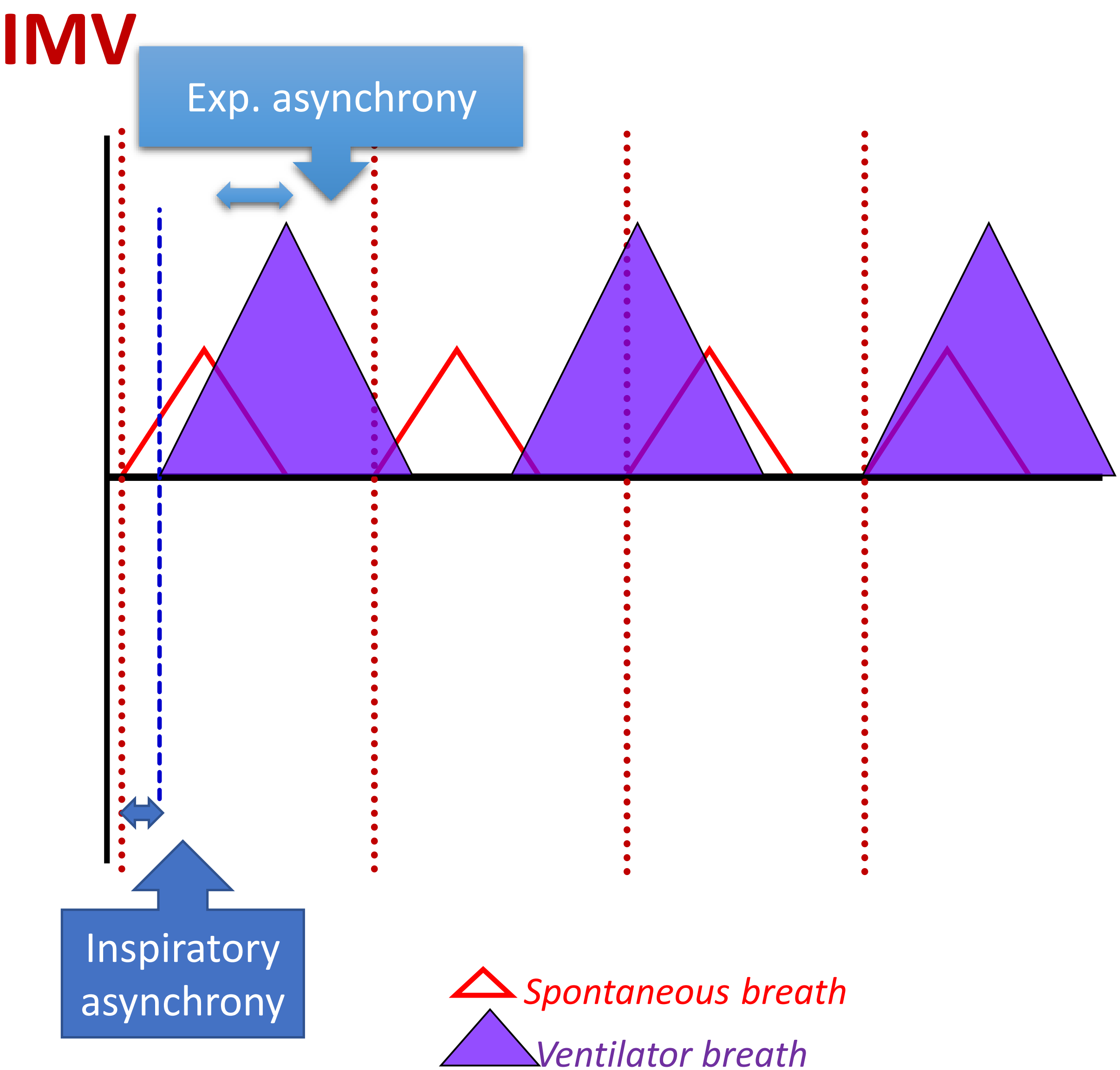




Clinician sets PEEP.
TV depends on PIP-PEEP, Ti and the respiratory system

Time-cycled pressure-limited ventilation (TCPLV)

Conventional mode



Asynchrony is the norm

Asynchrony

- Ineffective ventilation
  - ✓ Hypoxia and hypercarbia
  - ✓ Increased WOB
- Inadvertent PEEP/ Barotrauma and Volutrauma
  - Air trapping
  - Air leaks (PIE, pneumothorax)
- Interference with CBF/ fluctuations in ICP: IVH
- Comfort
- Need of sedation
- Weaning!

Overcoming asynchrony

- Increase rate
  - Inadvertent PEEP
  - Lung injury
- Increase PIP
  - Lung injury
  - Air leaks
- Sedation and paralysis
  - Unacceptable side effects

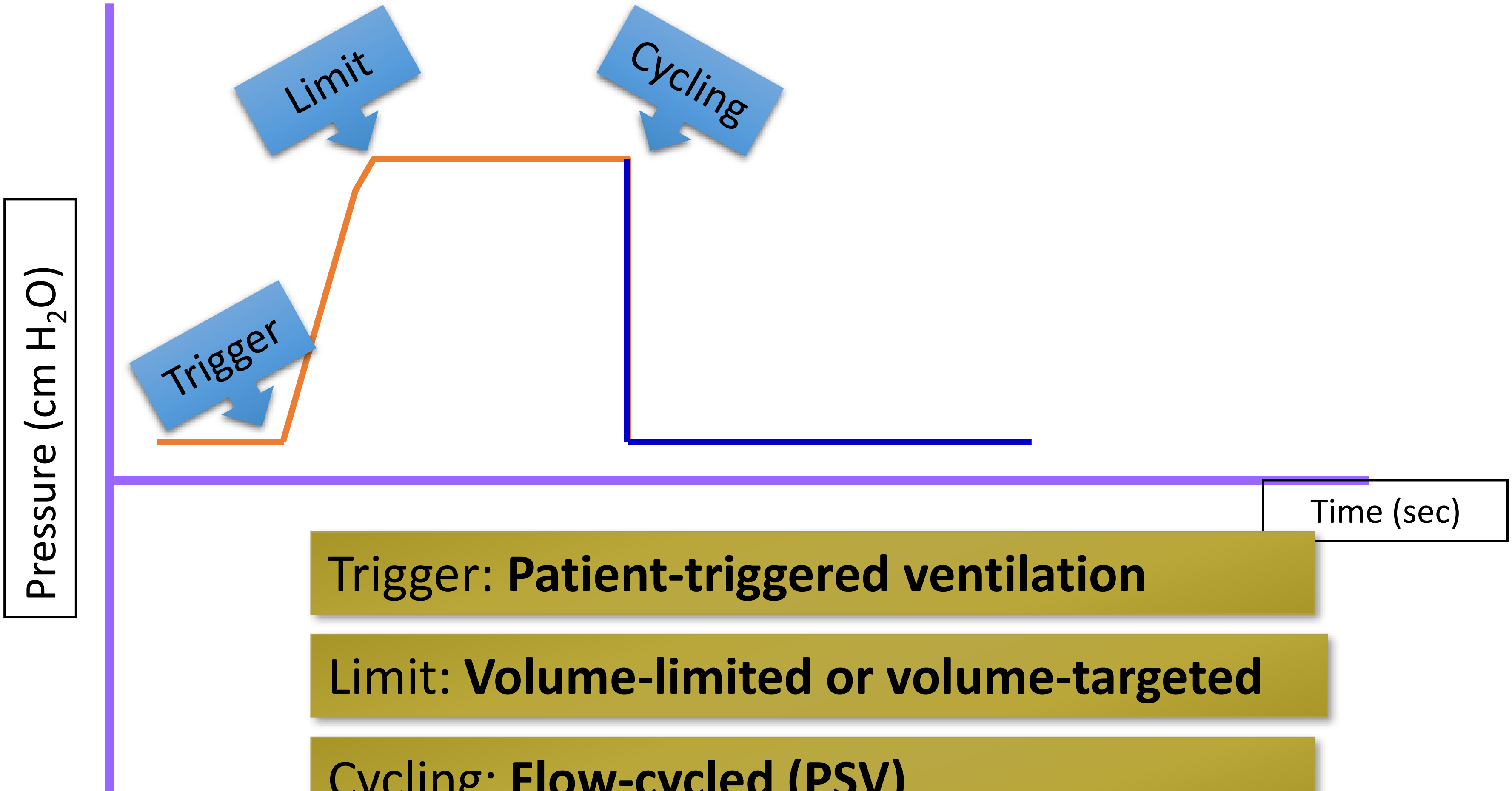
Newer modes of ventilation

Newer modes

- Not exactly **new!**
- Improvement over conventional ventilation
- Examples:
  - SIMV
  - SIPPV
  - PSV
  - Volume limited or volume targeted ventilation

Confusing terminologies!

Newer modes



Trigger: **Patient-triggered ventilation**

Limit: **Volume-limited or volume-targeted**

Cycling: **Flow-cycled (PSV)**

Patient-triggered ventilation (PTV)

Synchronized modes

- Delivery of a mechanical breath in response to the signal ('Trigger') from the baby
- Comprises three modes:

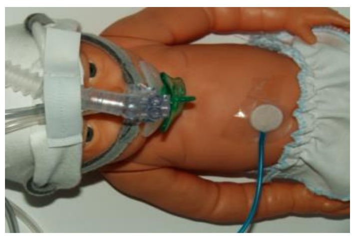
1. SIMV (synchronized IMV)
2. A/C (assist-control) or SIPPV
3. PSV (pressure support)

Different vents have different terminologies – PTV in SLE refers to A/C!

PTV

Trigger

Thoracic impedance

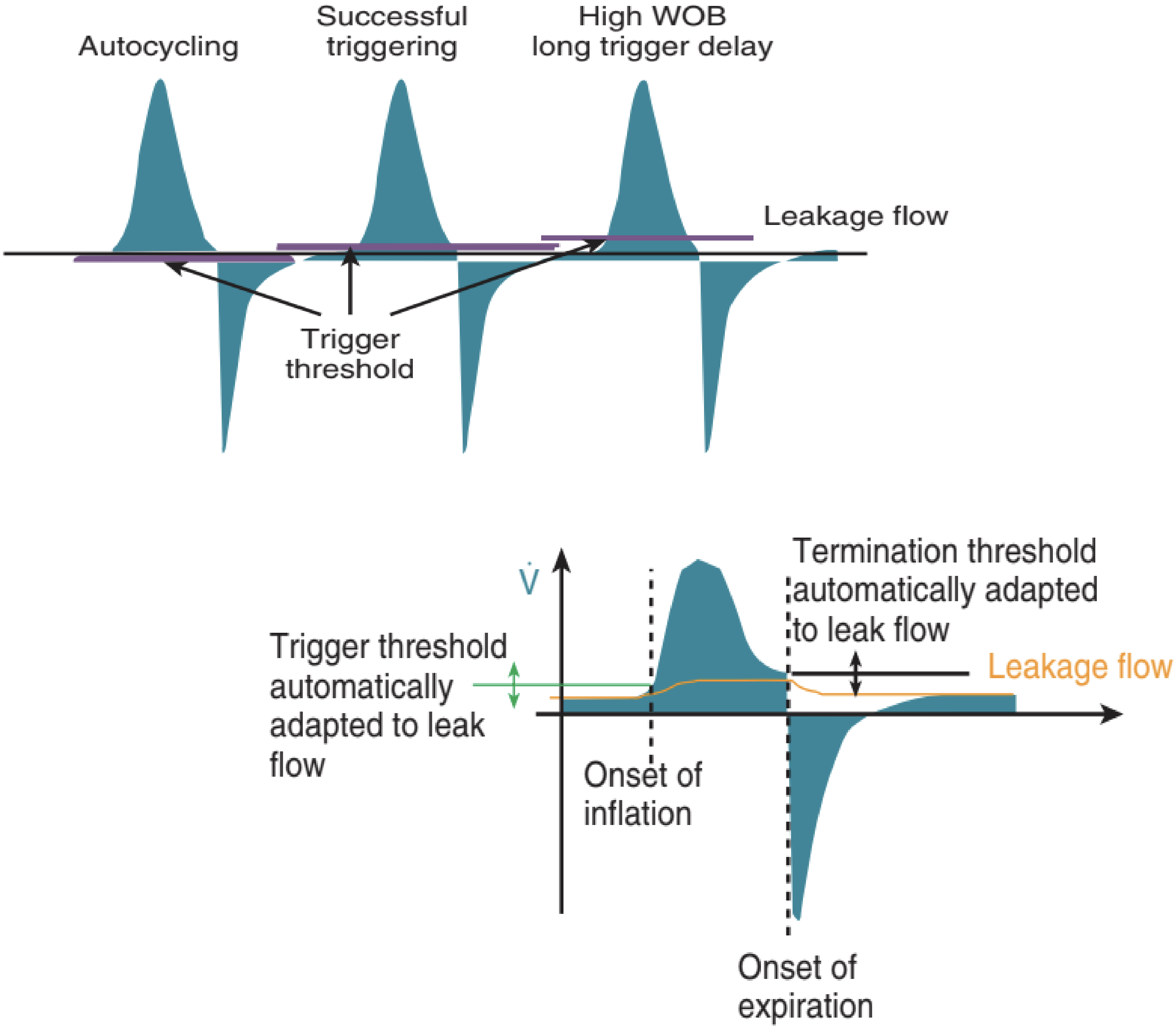


Graseby capsule

Flow sensor (heated wire anemometer)

Flow sensor (diff. variable orifice)

Pressure transducer


Autocycling
Successful triggering
High WOB long trigger delay
Leakage flow
Trigger threshold
V̇
Termination threshold automatically adapted to leak flow
Leakage flow
Trigger threshold automatically adapted to leak flow
Onset of inflation
Onset of expiration

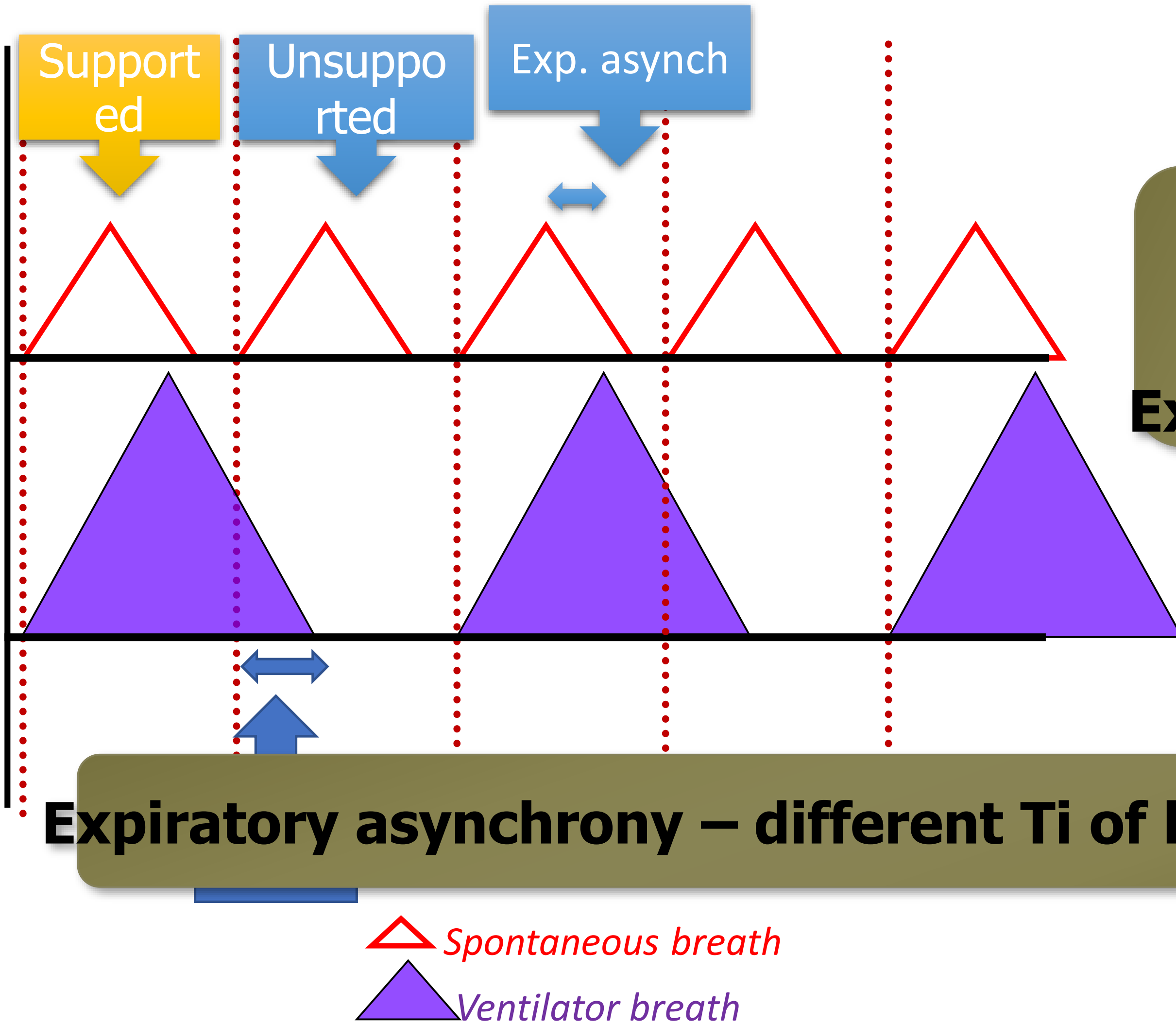
PTV

SIMV

- Supports only FIXED number of breaths
- If baby's spontaneous rate <set rate, all breaths will be supported;
  - In addition, vent gives MORE breaths (to achieve the set rate)
- If baby's rate > set, some breaths NOT supported

PTV

SIMV



**Asynchrony:
Insp – SOME breaths;
Exp – ALL breaths**

Expiratory asynchrony – different Ti of baby and vent

Summary

	SIMV	A/C	PSV	PSV+VG
Rate	Vent			
Ti	Vent			
PIP	Vent			
PEEP	Vent			

PTV

A/C

- Rates are not set; decided by baby
  - ALL spont. efforts that exceed trigger level are SUPPORTED
- A control rate helps in case of apnea
- Two modes
  - –Assist mode: All breaths will be supported
  - –Control mode: All breaths given by the vent

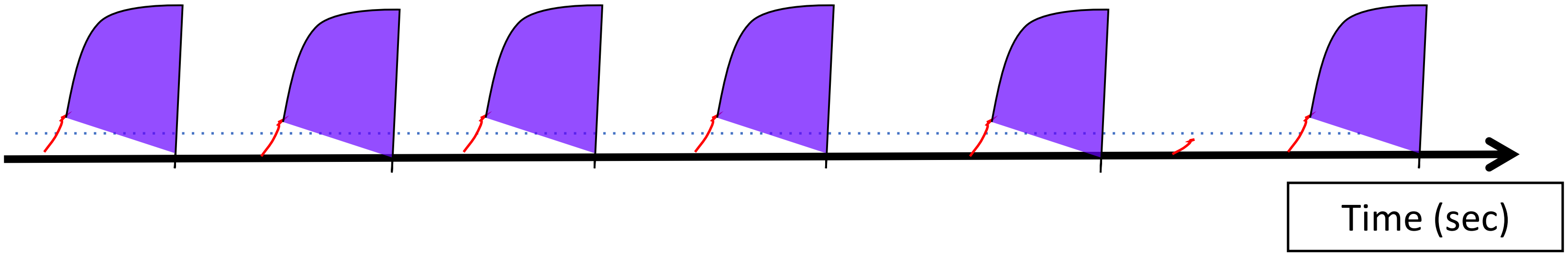
This mode involves either the delivery of a synchronized mechanical breath each time a spontaneous patient breath meeting threshold criteria is detected (assist) or the delivery of a mechanical breath at a regular rate in the event that the patient fails to exhibit spontaneous effort (control).

PTV

A/C

No set rates*

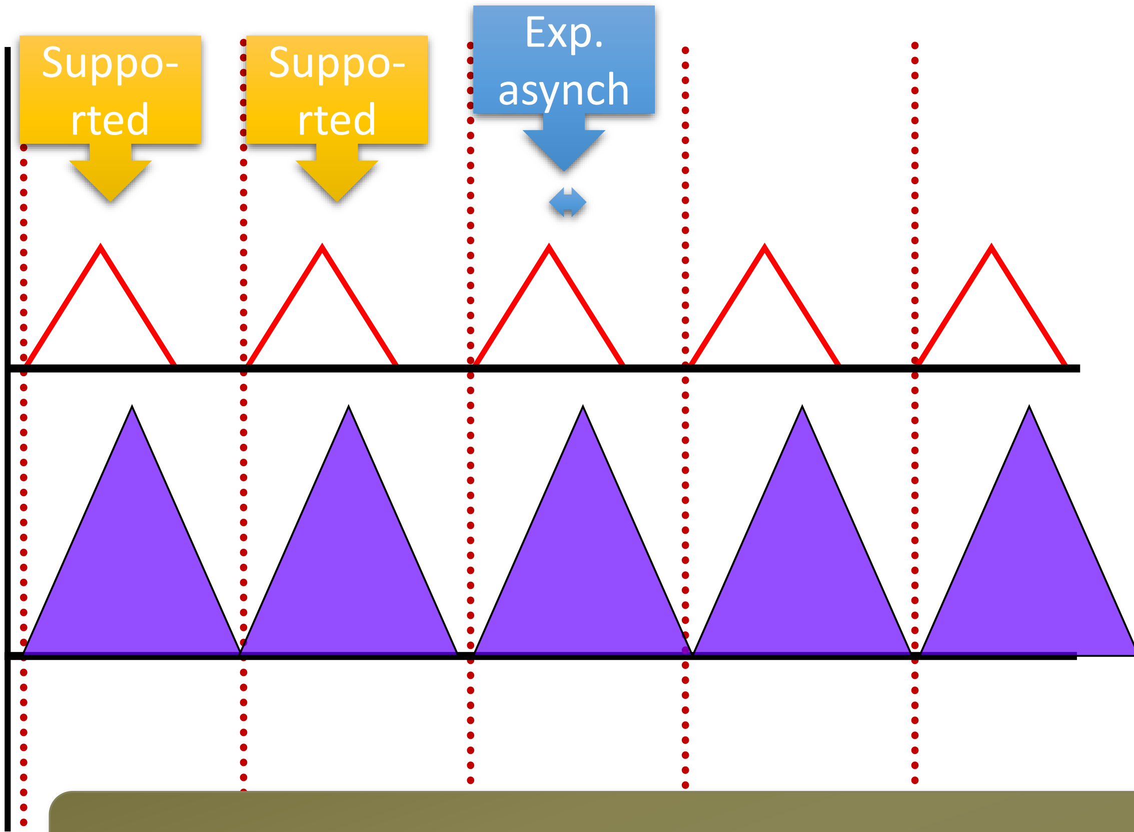
ALL breaths above trigger level – SUPPORTED



**only control rates are set*

PTV

A/C



Asynchrony:
Insp –NO;
Exp – ALL breaths

Expiratory asynchrony – different Ti of baby and vent

Spontaneous breath
Ventilator breath

Summary

Wean: Not by lowering rate but by lowering PIP

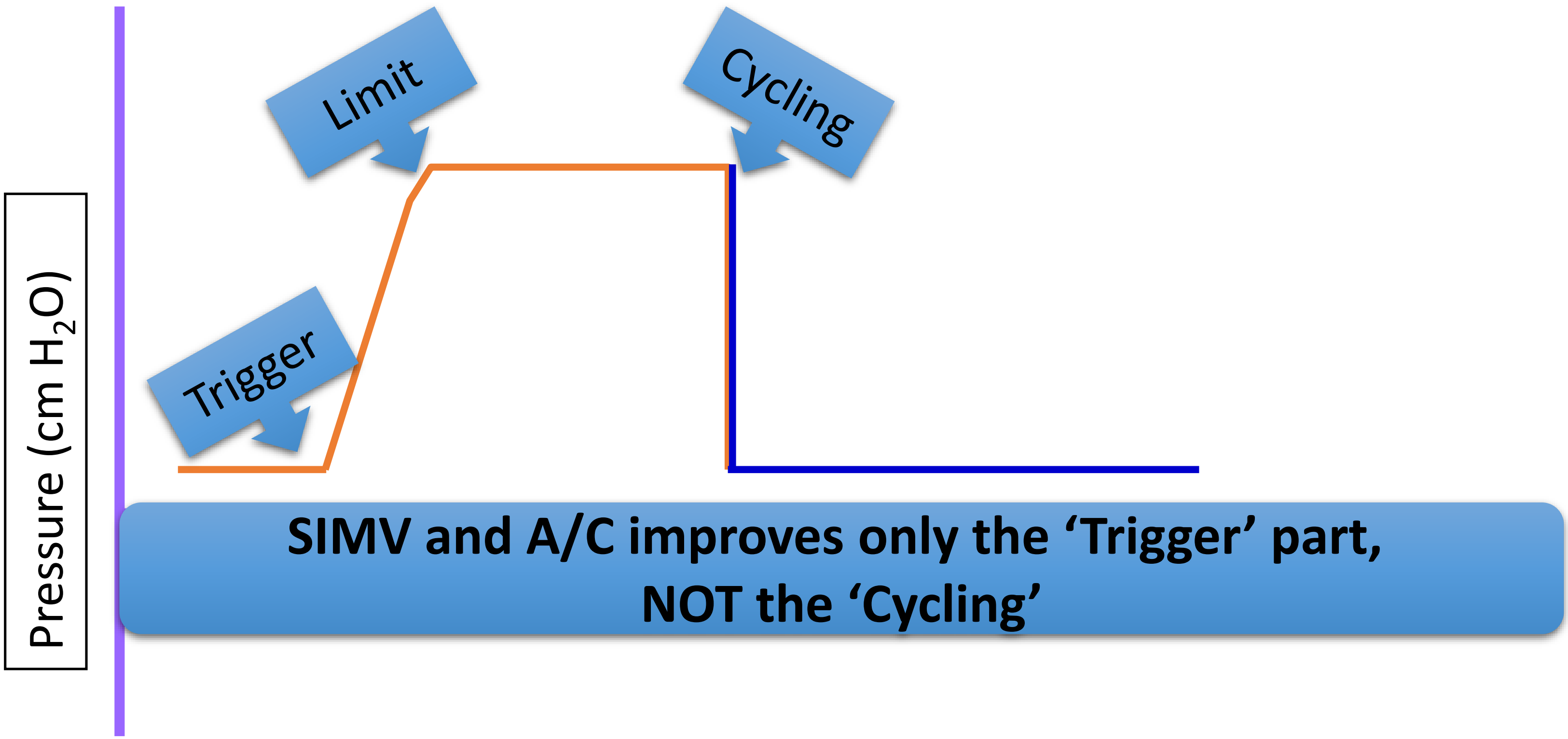
	SIMV	A/C	PSV	PSV+VG
Rate		**Baby**		
Ti		Vent		
PIP		Vent		
PEEP		Vent		

Lower work of breathing as compared with SIMV

PTV

PSV

Issue with SIMV and A/C



PTV

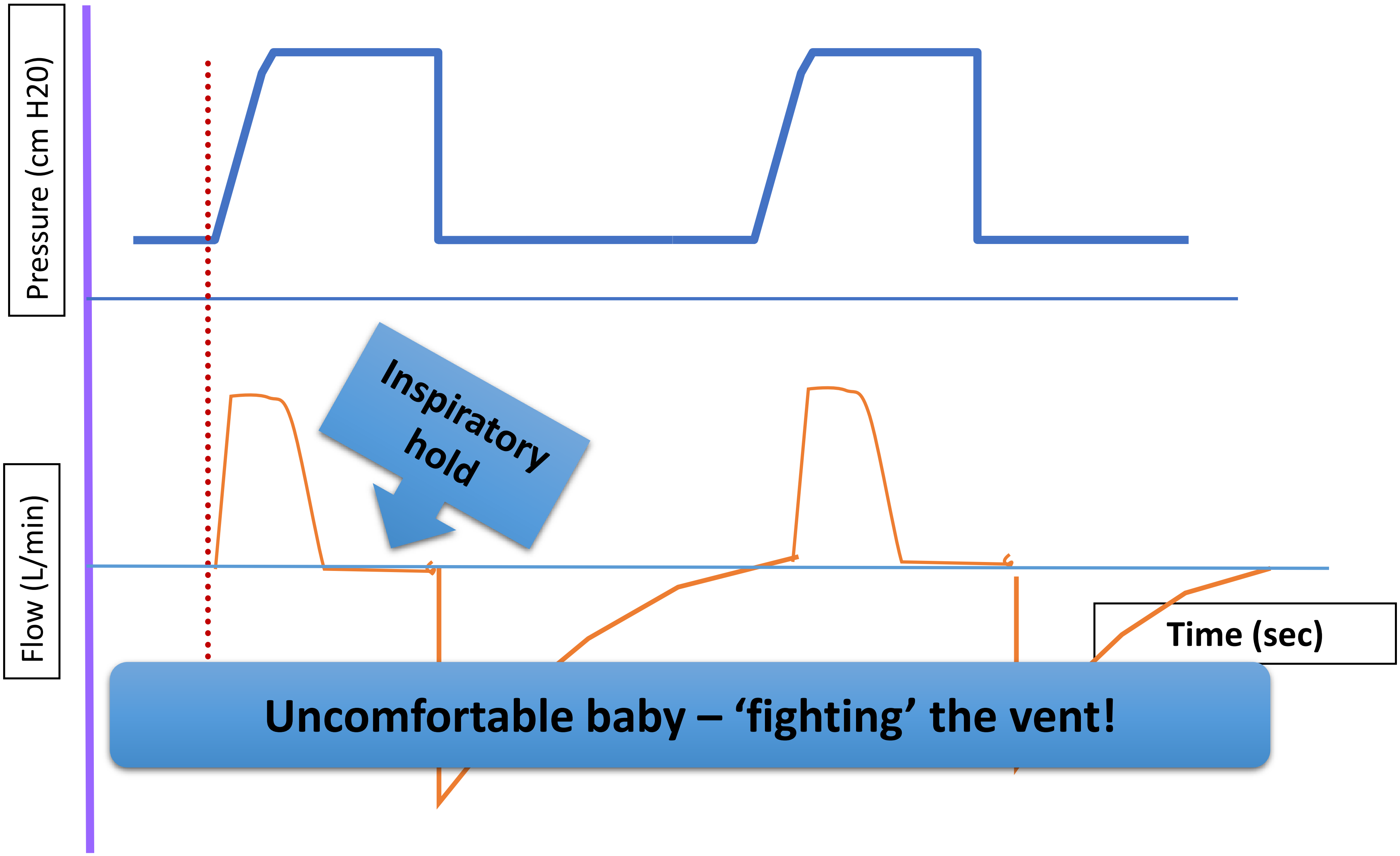
PSV

Issue with SIMV and A/C

- Baby’s Ti – always shorter than vent Ti

Different Ti – Expiratory asynchrony
PSV is also called flow cycled ACV

Issue with SIMV and A/C



Uncomfortable baby – ‘fighting’ the vent!

What is the alternative?

Second signal detection system that determines when patient inspiratory effort is about to cease and then synchronizes the termination of the mechanical breath to this event.

Flow cycling

Flow-derived signal is also used to terminate inspiration and to permit the total synchronization of spontaneous and mechanical breaths throughout the entire respiratory cycle

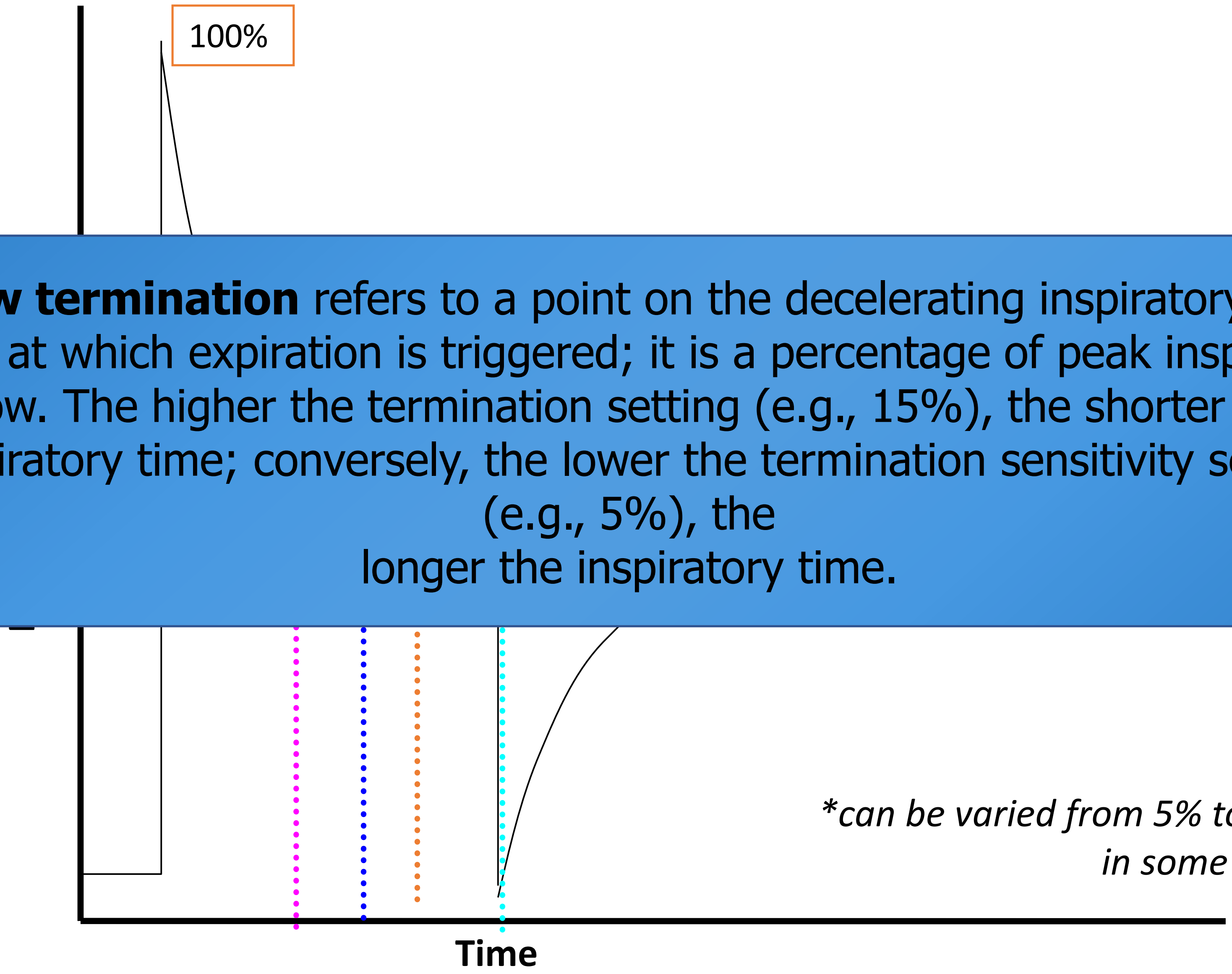
PTV

PSV

- Improves ‘Cycling’ part in addition to ‘Trigger’
- Flow-cycled and NOT time-cycled
  - Inspiration ends and expiration begins after a particular flow is reached

Flow cycling – ‘Termination sensitivity’

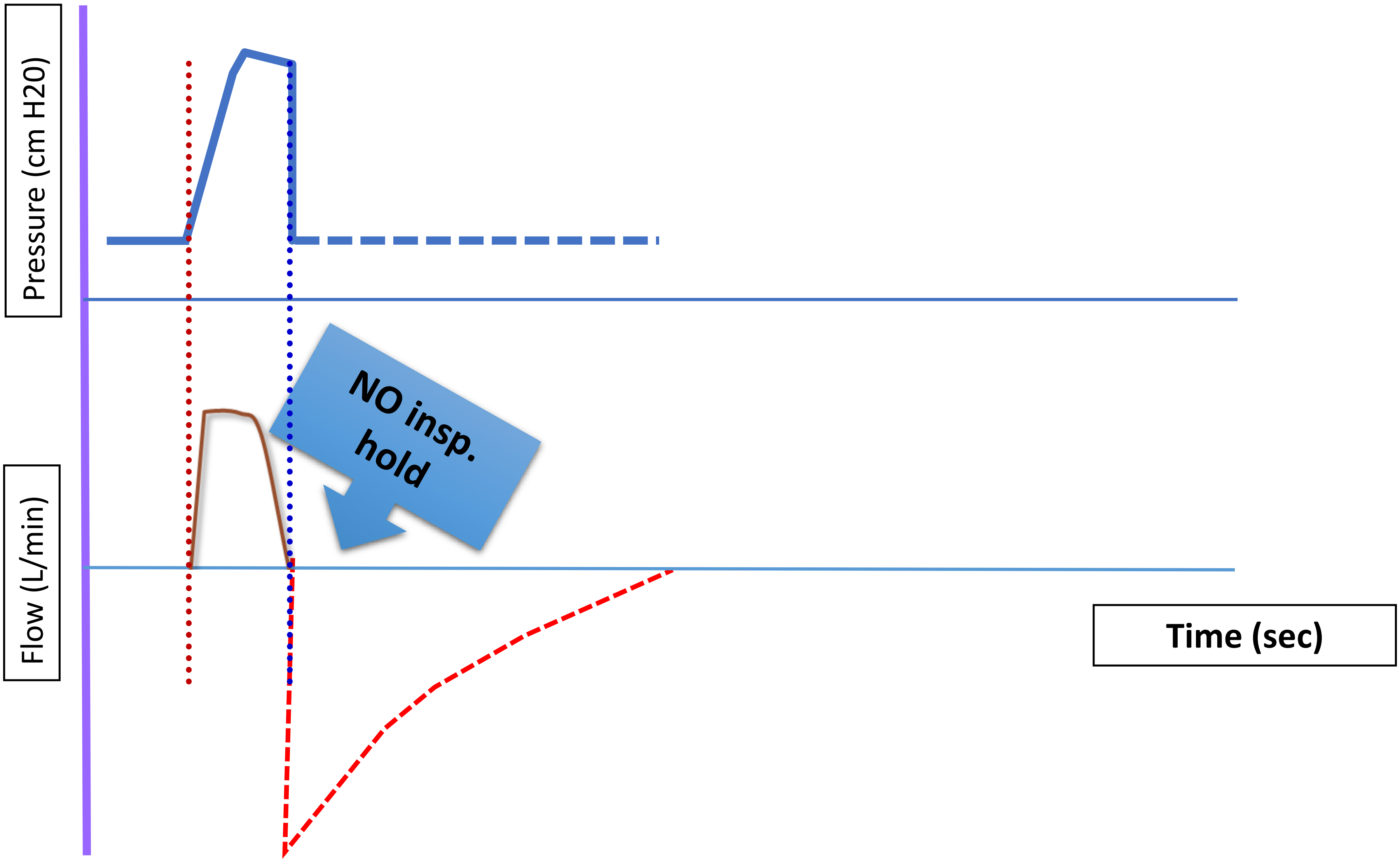
Termination sensitivity



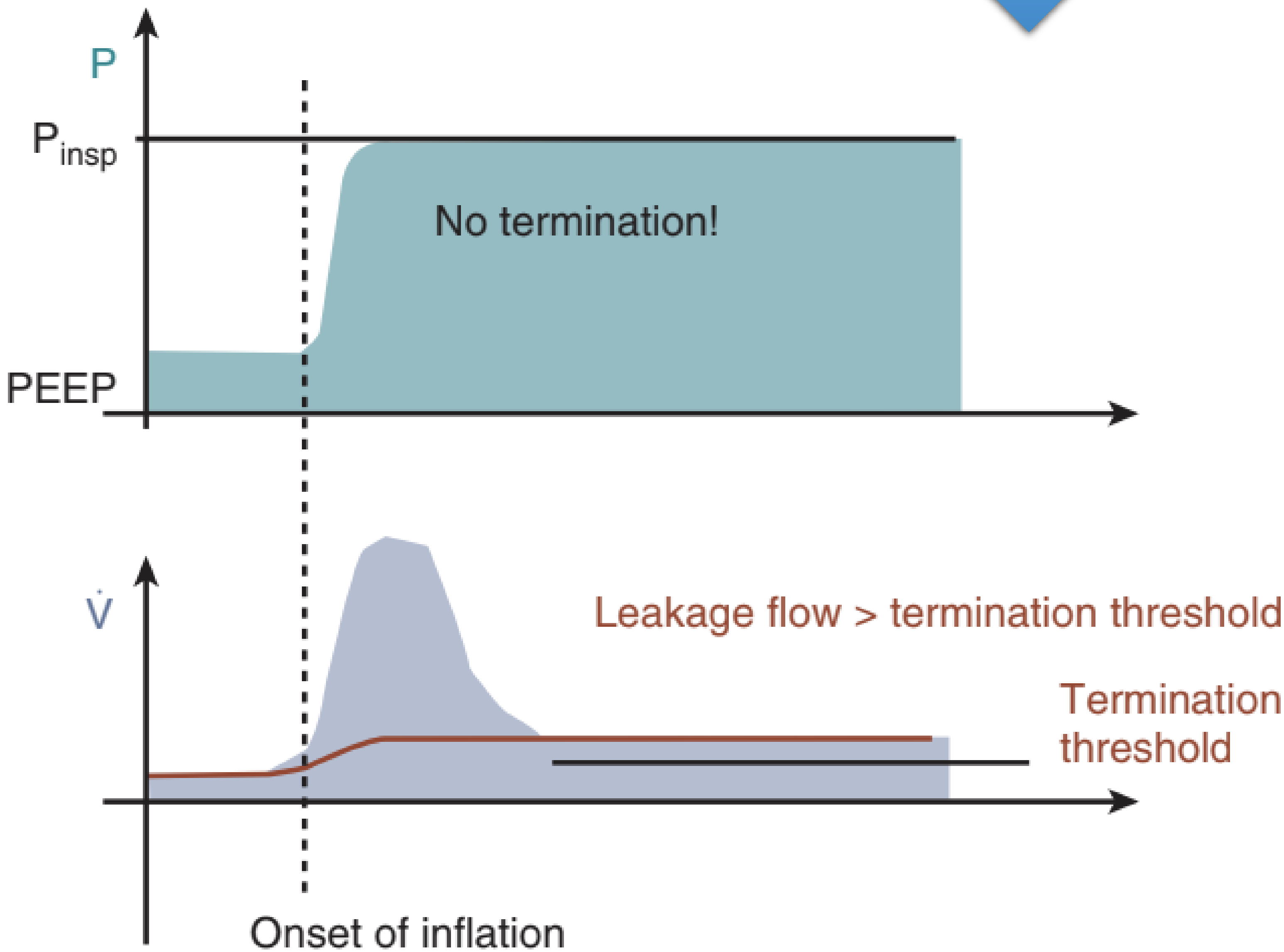
Flow termination refers to a point on the decelerating inspiratory flow curve at which expiration is triggered; it is a percentage of peak inspiratory flow. The higher the termination setting (e.g., 15%), the shorter the inspiratory time; conversely, the lower the termination sensitivity setting (e.g., 5%), the
longer the inspiratory time.

**can be varied from 5% to 25% in some vents*

PSV – termination sensitivity



Alternative: manually set Ti OR manually set termination criteria OR ventilator automatically compensates!



Trigger Delay

- Trigger delay (*system response time):* interval between signal detection and the rise in pressure at the proximal airway.
- Trigger delay must be minimal.
- E.g. Ti is 0.2 second (200 msec) will

  already be halfway through the inspiratory phase if the trigger delay is longer than 100 msec.

Problems with PTV

- False trigger
- *Hiccups*
- *Auto-cycling (excessive condensation ("rainout") in the ventilator circuit or from endotracheal tube leaks or cardiac impulses)*

PTV

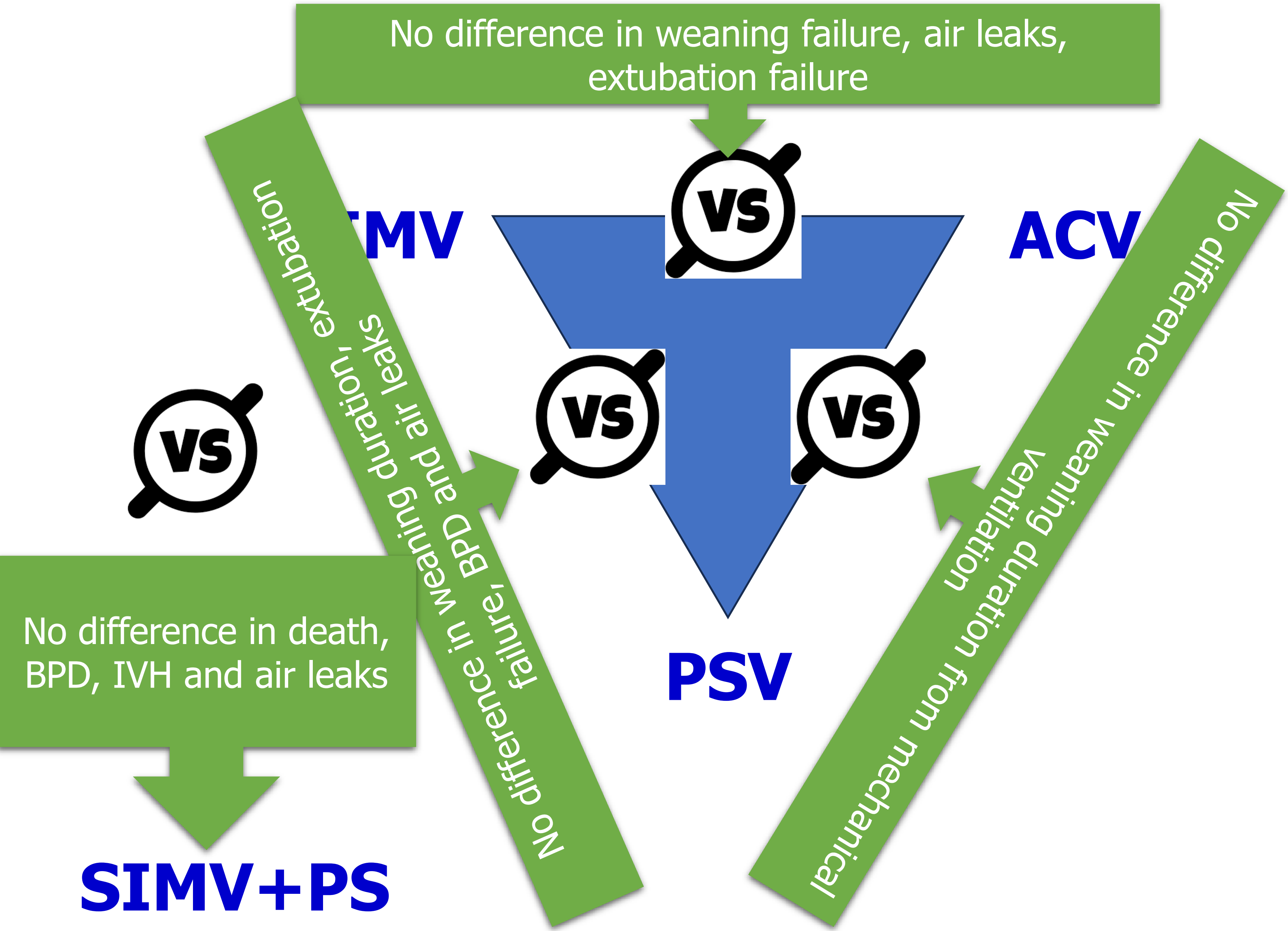
PSV

- Flow cycling – baby controls Ti
- Baby inhales fast, peak flow reaches early, 15% of peak flow reaches early
  - Ti will be short
- Baby inhales slowly (‘sigh’ breath), peak flow is reached late, 15% peak flow is late
  - Ti will be long

Summary

	SIMV	A/C	PSV	PSV+VG
Rate			**Baby**	
Ti			**Baby**	
PIP			Vent	
PEEP			Vent	

Evidence



No difference in weaning failure, air leaks, extubation failure
IMV
ACV
PSV
SIMV+PS
VS
VS
VS
VS
No difference in weaning duration, extubation failure, BPD and air leaks
No difference in weaning duration from mechanical ventilation
No difference in death, BPD, IVH and air leaks

PTV

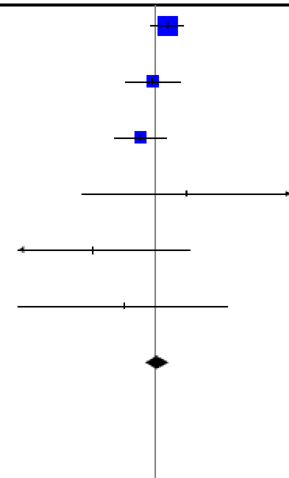
Analysis 2.2. Comparison 2 ACV / SIMV vs CMV, Outcome 2 Airleaks.

Review: Synchronized mechanical ventilation for respiratory support in newborn infants

Comparison: 2 ACV / SIMV vs CMV

Outcome: 2 Airleaks

Study or subgroup	ACV/SIMV n/N	CMV n/N	Risk Ratio M-H,Fixed,95% CI	Weight	Risk Ratio M-H,Fixed,95% CI
Baumer 2000	62/465	47/459		47.4 %	1.30 [0.91, 1.86]
Beresford 2000	20/193	21/193		21.0 %	0.95 [0.53, 1.70]
Bernstein 1996	18/167	24/160		24.6 %	0.72 [0.41, 1.27]
Chan 1993	2/20	1/20		1.0 %	2.00 [0.20, 20.33]
Chen 1997	1/31	4/31		4.0 %	0.25 [0.03, 2.11]
Donn 1994	1/15	2/15		2.0 %	0.50 [0.05, 4.94]
Total (95% CI)	**891**	**878**		**100.0 %**	**1.03 [0.80, 1.34]**



Total events: 104 (ACV/SIMV), 99 (CMV)

Heterogeneity: $Chi^2 = 5.64$, df = 5 (P = 0.34); $I^2 = 11\%$

Test for overall effect: Z = 0.25 (P = 0.80)

No reduction in air-leaks

PTV

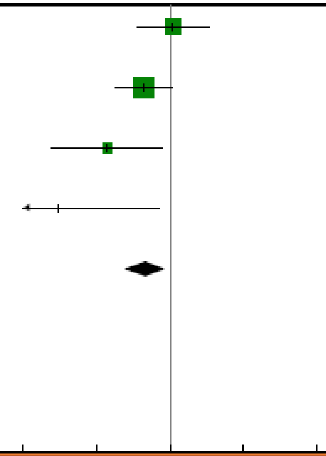
Analysis 2.3. Comparison 2 ACV / SIMV vs CMV, Outcome 3 Duration of ventilation (hours).

Review: Synchronized mechanical ventilation for respiratory support in newborn infants

Comparison: 2 ACV / SIMV vs CMV

Outcome: 3 Duration of ventilation (hours)

Study or subgroup	ACV/SIMV N	Mean(SD)	CMV N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Weight	Mean Difference IV,Fixed,95% CI
Baumer 2000	465	300 (403.2)	459	295.2 (360)		30.8 %	4.80 [-44.47, 54.07]
Beresford 2000	193	124.8 (153.6)	193	160.8 (220.8)		51.9 %	-36.00 [-73.95, 1.95]
Chen 1997	31	156 (122)	31	242 (175)		13.3 %	-86.00 [-161.10, -10.90]
Donn 1994	15	119 (156)	15	271 (218)		4.1 %	-152.00 [-287.66, -16.34]
Total (95% CI)	**704**		**698**			**100.0 %**	**-34.78 [-62.11, -7.44]**



Heterogeneity: $Chi^2 = 7.14$, df = 3 (P = 0.07); I^2 =58%

Test for overall effect: Z = 2.49 (P = 0.013)

Test for subgroup differences: Not applicable

Duration of ventilation less by 34 hrs

PTV

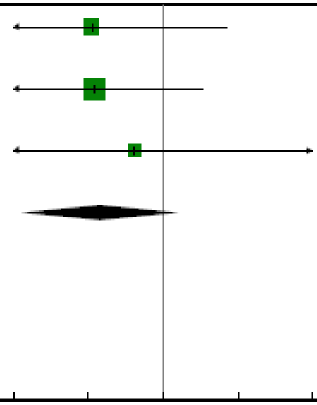
Analysis 3.1. Comparison 3 ACV or PRVCV vs SIMV, Outcome 1 Duration of weaning (hours).

Review: Synchronized mechanical ventilation for respiratory support in newborn infants

Comparison: 3 ACV or PRVCV vs SIMV

Outcome: 1 Duration of weaning (hours)

Study or subgroup	ACV N	ACV Mean(SD)	SIMV N	SIMV Mean(SD)	Mean Difference IV,Fixed,95% CI	Weight	Mean Difference IV,Fixed,95% CI
Chan 1994	20	77.6 (102.3)	20	124.9 (178)		33.4 %	-47.30 [-137.28, 42.68]
Dimitriou 1995a	20	53 (95)	20	99 (135)		51.6 %	-46.00 [-118.35, 26.35]
Dimitriou 1995b	20	118 (265)	20	137 (153)		15.0 %	-19.00 [-153.11, 115.11]
Total (95% CI)	**60**		**60**			**100.0 %**	**-42.38 [-94.35, 9.60]**



Heterogeneity: $Chi^2 = 0.14$, df = 2 (P = 0.93); $I^2 = 0.0\%$

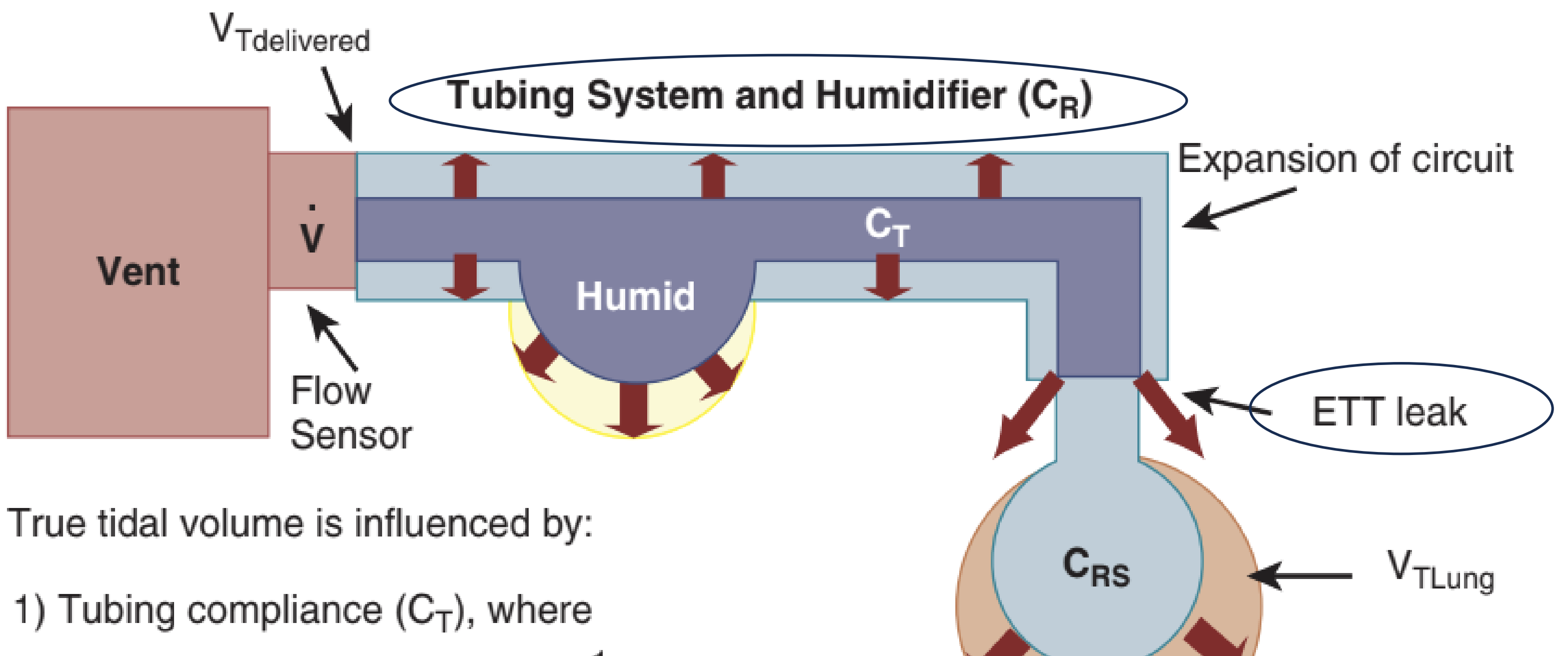
Test for overall effect: Z = 1.60 (P = 0.11)

Test for subgroup differences: Not applicable

Trend towards reduction in duration of ventilation with A/C

Volume ventilation and NAVA

VC vs. VT vs. VG



What is controlled is the volume injected into the ventilator circuit, not the VT that enters the patient's lungs!

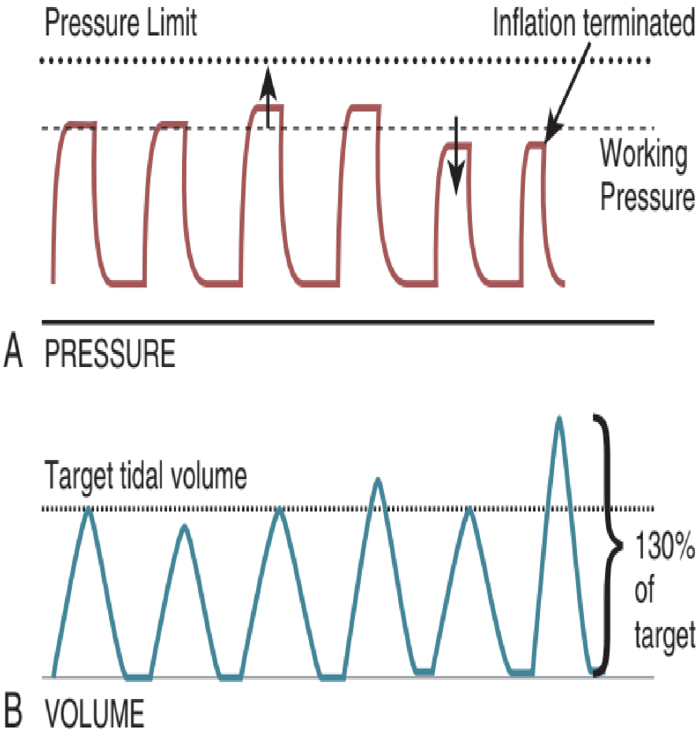
In large patients with cuffed ETTs, this loss is insignificant and easily compensated!

What is volume targeted?

- VTV is designed to deliver a target tidal volume.
- By real-time microprocessor-directed adjustments of inflation pressure.
- Some devices regulate tidal volume delivery based on flow measurement during inflation and others during exhalation.

What is VG?

- Draeger Babylog 8000; the VN 500, 600, and 800
- The microprocessor compares the exhaled VT of the previous inflation and adjusts the working pressure
- The algorithm limits the pressure increment from one inflation to the next to a percentage of the amount needed to reach the target VT, with a maximum increase of 3 cm H2O.



An obvious advantage of VG is that weaning occurs automatically, in real-time, and requires fewer blood gas measurements.

Evidence*

- 20 RCT; 16 parallel group and four cross over
- Moderate quality evidence- Reduction in the primary outcome, death or BPD at 36 weeks gestation (typical RR 0.73, 95% CI 0.59 to 0.89; typical NNTB 8, 95% CI 5 to 20)
- Decrease in rates of pneumothorax (typical RR 0.52, 95% CI 0.31 to 0.87; typical NNTB 20, 95% CI 11 to 100)
- Decrease in mean days of mechanical ventilation by 1.35 days

Cochrane Library — Trusted evidence. Informed decisions. Better health.

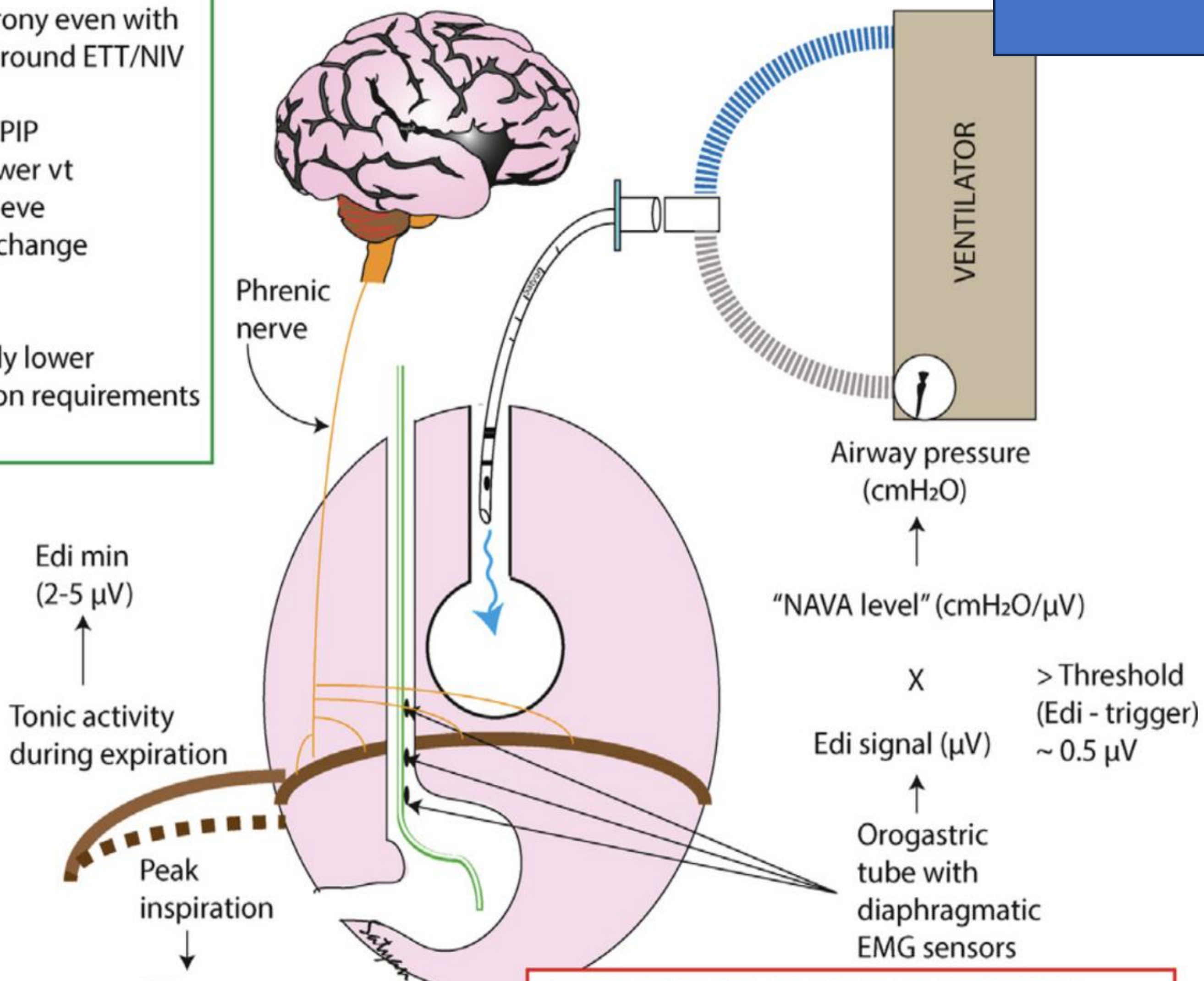
Klingenberg C et al, https://doi.org/10.1002/14651858.CD003666.pub4

NAVA

ADVANTAGES:
Synchrony even with leaks around ETT/NIV

Lower PIP and lower vt to achieve gas exchange

Possibly lower sedation requirements



DISADVANTAGES OR CONTRAINDICATIONS:
Not effective if there is no respiratory drive, phrenic nerve palsy, inability to place NG tube (tracheo-esophageal fistula or perforation

Evidence*

Improved patient-ventilator interaction

Less oxygen and sedation requirements

Less apnea

Lower peak pressures

Improved comfort and

Improved extubation success

*Small sample size, retrospective, physiological studies, no long-term data, hardly any RCT, review, consensus statements

Stein H, Firestone K, Beck J. Neurally adjusted ventilatory assist (NAVA). In: Donn SM, Mammel MC, Van Kaam AH, editors. Manual of neonatal respiratory care. 5th edition. New York: Springer Science; 2021, in press.

Contraindications for the use of NAVA

Impaired respiratory drive:

- HIE
- Brainstem stroke
- Overwhelming sepsis
- Oversedation or paralysis

Inability to place the NAVA catheter:

- TEF
- Esophageal perforation or surgery
- Abnormal esophagus
- Phrenic nerve lesions

Summary

- Newer modes do offer hope and seem promising
- Ventilator is only a tool in the hands of the clinician
- Tool can be used well, or not!
- Abandon the term “ventilator-induced lung injury” in favour of “physician-induced lung injury”

Thanks