Small Breaths, Big Impact: Delivering Lung-Protective Ventilation in the ELBW Population

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Director of Respiratory, Pulmonary, & Asthma Program

CHOC

Rady Children's Health

APEX 2025-2026

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Disclosures

- **American Association for Respiratory Care (AARC)**
  - Board of Directors - Chair, Neonatal/Pediatric Section
- **American Academy of Pediatrics (AAP) Pediatric Acute & Critical Care Quality Network (PACCQN)**
  - Expert Workgroup Member
- **National Board for Respiratory Care (NBRC)**
  - Consultant – Neonatal/Pediatric Specialty Exam
- **Children's Hospital Association (CHA)**
  - Steering Advisory Committee – Respiratory Directors Forum
- **National Pediatric Disaster Coalition (NPDC)**
  - Consultant, AARC Liaison

Committee Work:

- Clinical Practice Guidelines (CPG) Committee: Pediatric Aerosol Therapy
- Leadership Grand Rounds (LGR) Committee
- Inclusion, Diversity, Equity, Access, & Accountability (IDEAA) Committee
- Safe and Effective Staffing Guide (SESG) Expert Panel & Taskforce – Committee Member and BOD Liaison
- Clinical Educators Community – BOD Liaison
- Speakers Academy Mentor
- Emerging Leaders Program Mentor
- Critical Care Transport Section: BOD Liaison
- CF Microcredential Taskforce – BOD Liaison

Paid consultant of:

Fisher & Paykel Healthcare

Vero Biotech

I do not have any conflicts of interest as it pertains to this topic.

References to specific ventilators reflect the proprietary nature of certain ventilation modes. Device names are used solely for educational illustration and not as product endorsements.

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Objectives

- Describe the pathophysiology of ventilator-induced lung injury and the importance of lung-protective tidal volume delivery in ELBW neonates.
- Review the clinical evidence supporting lung-protective ventilation strategies and low-tidal volume delivery in ELBW infants.
- Apply practical bedside strategies to optimize low-tidal volume ventilation and improve respiratory outcomes in the ELBW NICU population.

Why Does This Matter?

- Mechanical ventilation can inflict and accentuate lung injury
- VILI is an important risk factor in ELBW infants for developing bronchopulmonary dysplasia (BPD)
- Up to 95% of surviving ELBW infants will be exposed to mechanical ventilation in NICU *(Keszler, 2015)*
  - 30-80% require MV in first few days of life *(Stoll, 2015; Shi, 2020)*
- Prolonged mechanical ventilation increases risk of:
  - Death
  - Moderate-severe BPD
  - Pulmonary hypertension
  - ROP
  - Periventricular leukomalacia
  - Poor growth
  - Neurological impairment
    - *(Dou 2023, Choi 2018)*

Lung (and Brain) Protective Strategies are necessary in the NICU!

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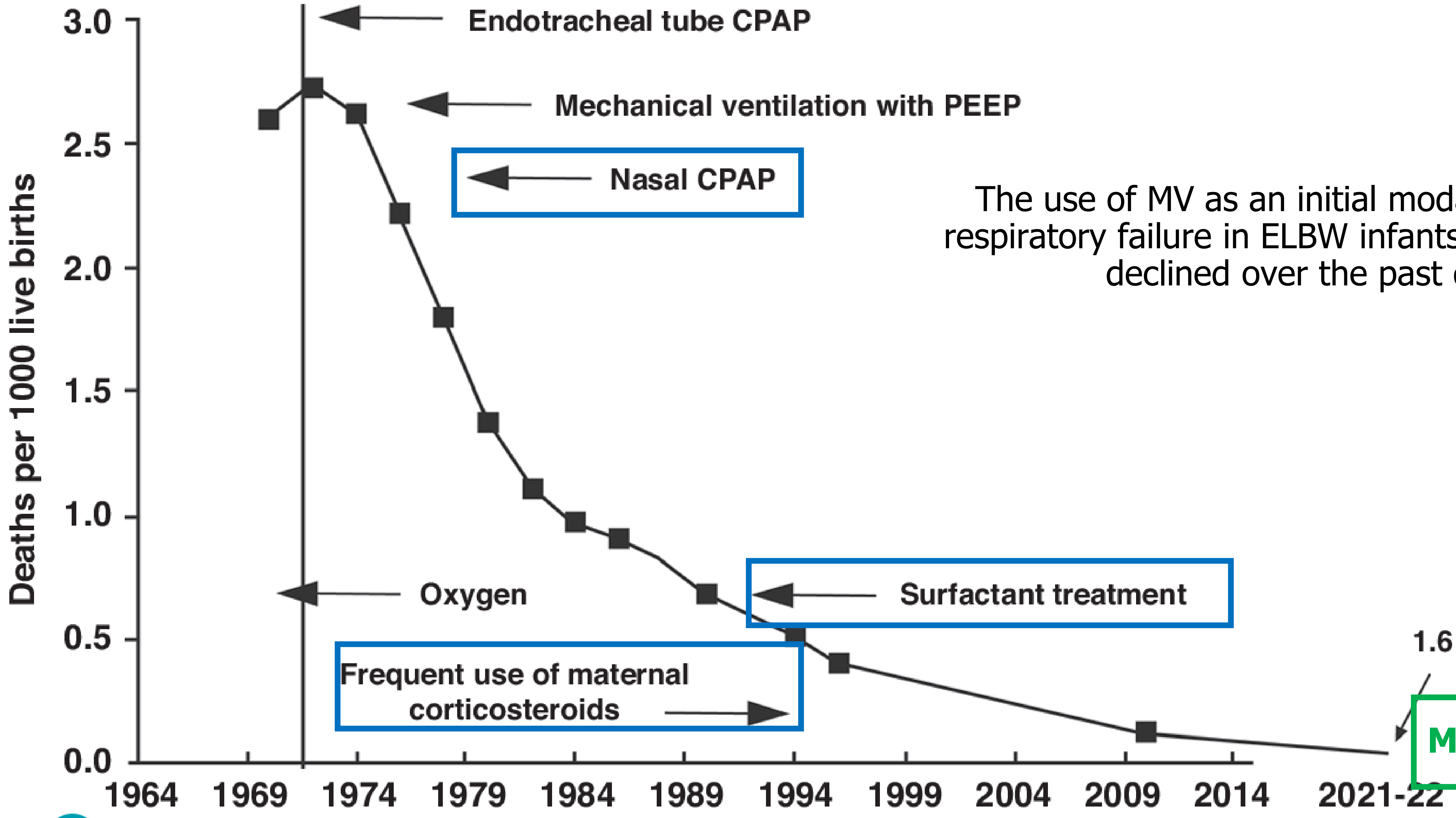
RDS: How Are We Doing?

Mortality Rate: 50%



The use of MV as an initial modality to mitigate respiratory failure in ELBW infants has substantially declined over the past decade

Mortality Rate: <2%

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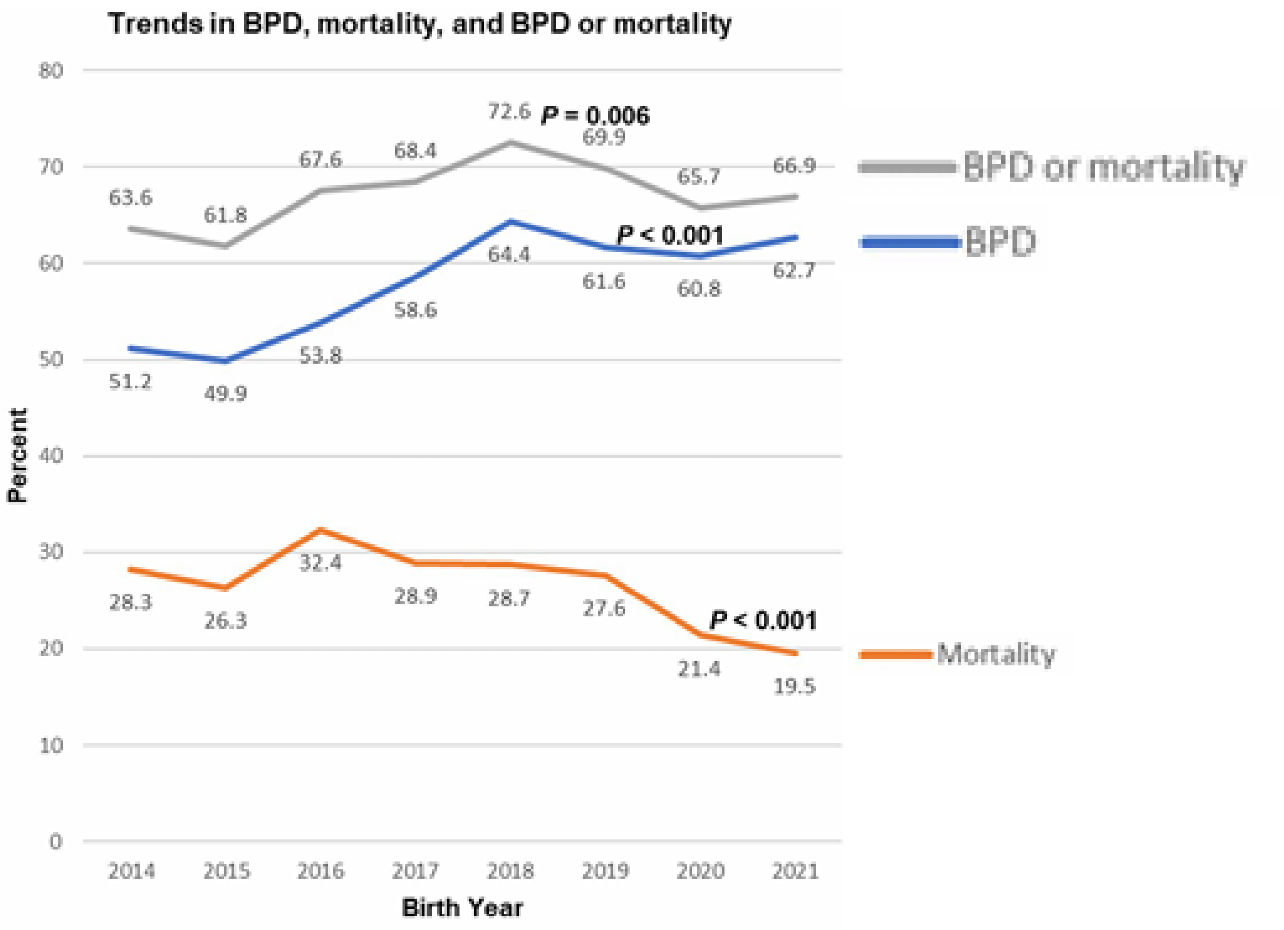
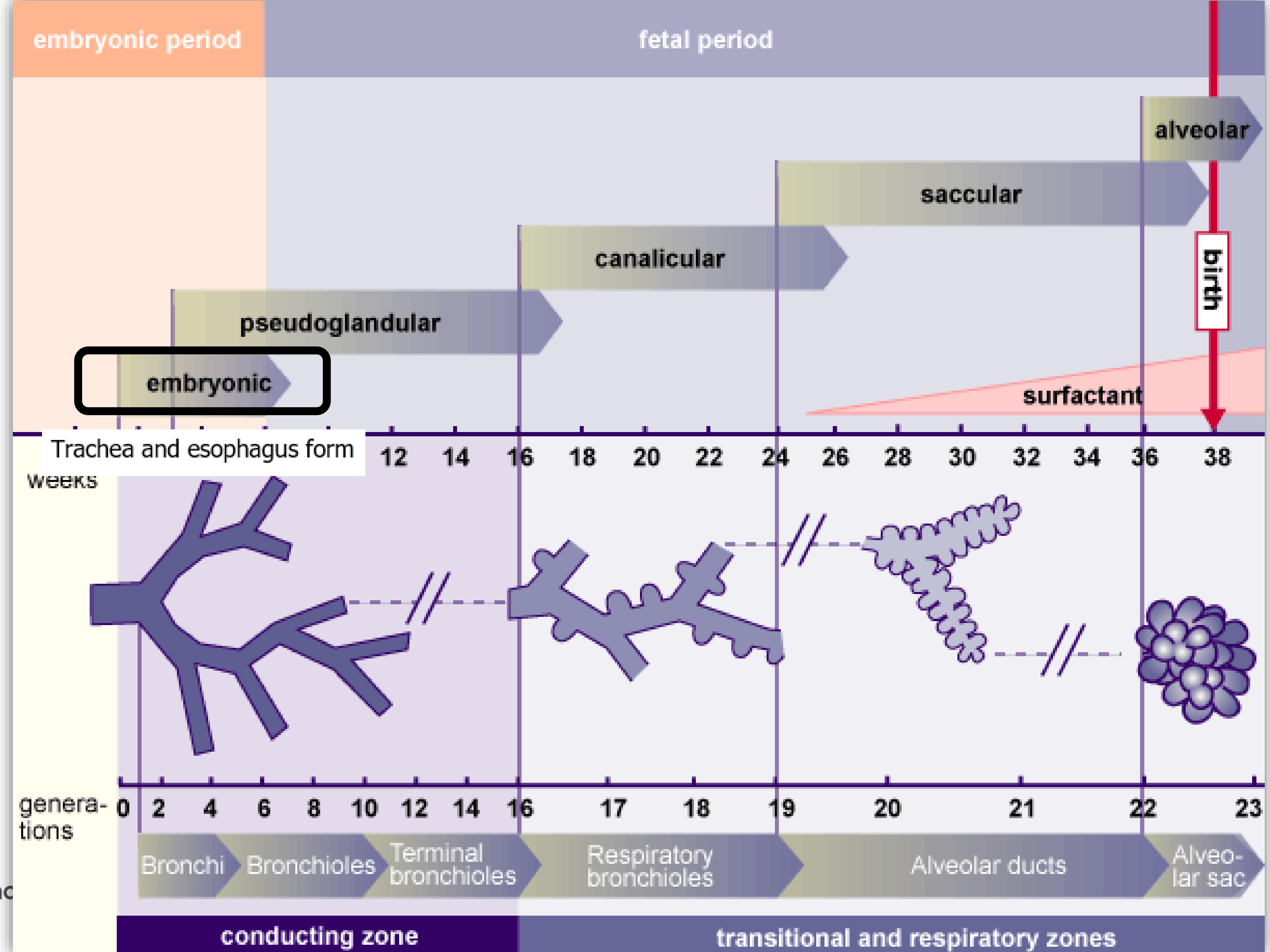
Jobe, A.H. Respiratory distress syndrome is the poster child for neonatology. *Pediatr Res* **98**, 59–64 (2025).

Increased bronchopulmonary dysplasia along with decreased mortality in extremely preterm infants

Ga Won Jeon[1,5], Minkyung Oh[2,5] & Yun Sil Chang[3,4]



Jeon GW, Oh M, Chang YS. Increased bronchopulmonary dysplasia along with decreased mortality in extremely preterm infants. Sci Rep. 2025 Mar 13;15(1):8720



embryonic period
fetal period
alveolar
saccular
canalicular
birth
pseudoglandular
embryonic
surfactant
Trachea and esophagus form
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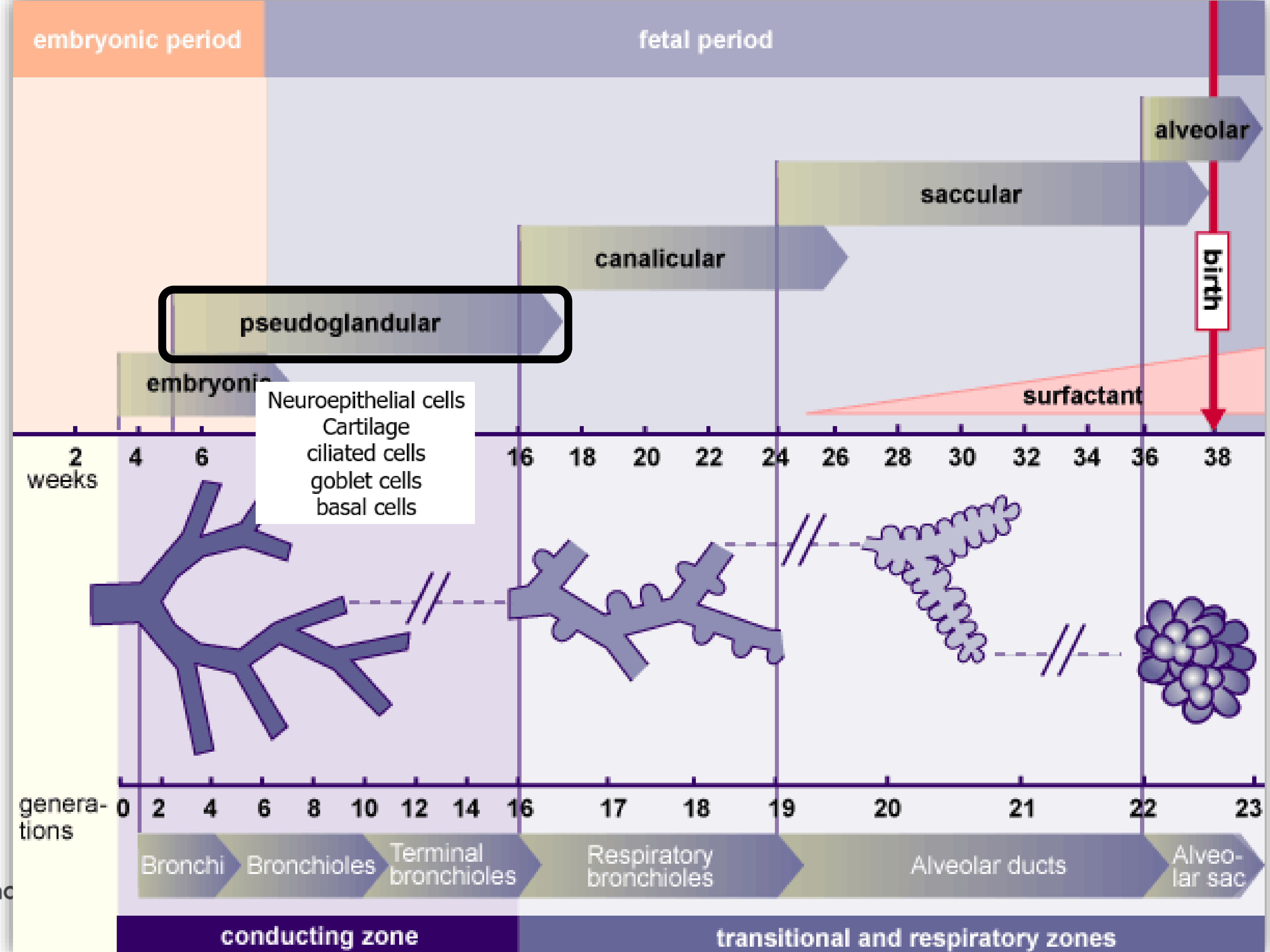
Bronchioles
Terminal bronchioles
Respiratory bronchioles
Alveolar ducts
Alveo-lar sac
conducting zone
transitional and respiratory zones



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fetal period
alveolar
saccular
canalicular
birth
pseudoglandular
embryonic
surfactant
Neuroepithelial cells
Cartilage
ciliated cells
goblet cells
basal cells
2 weeks
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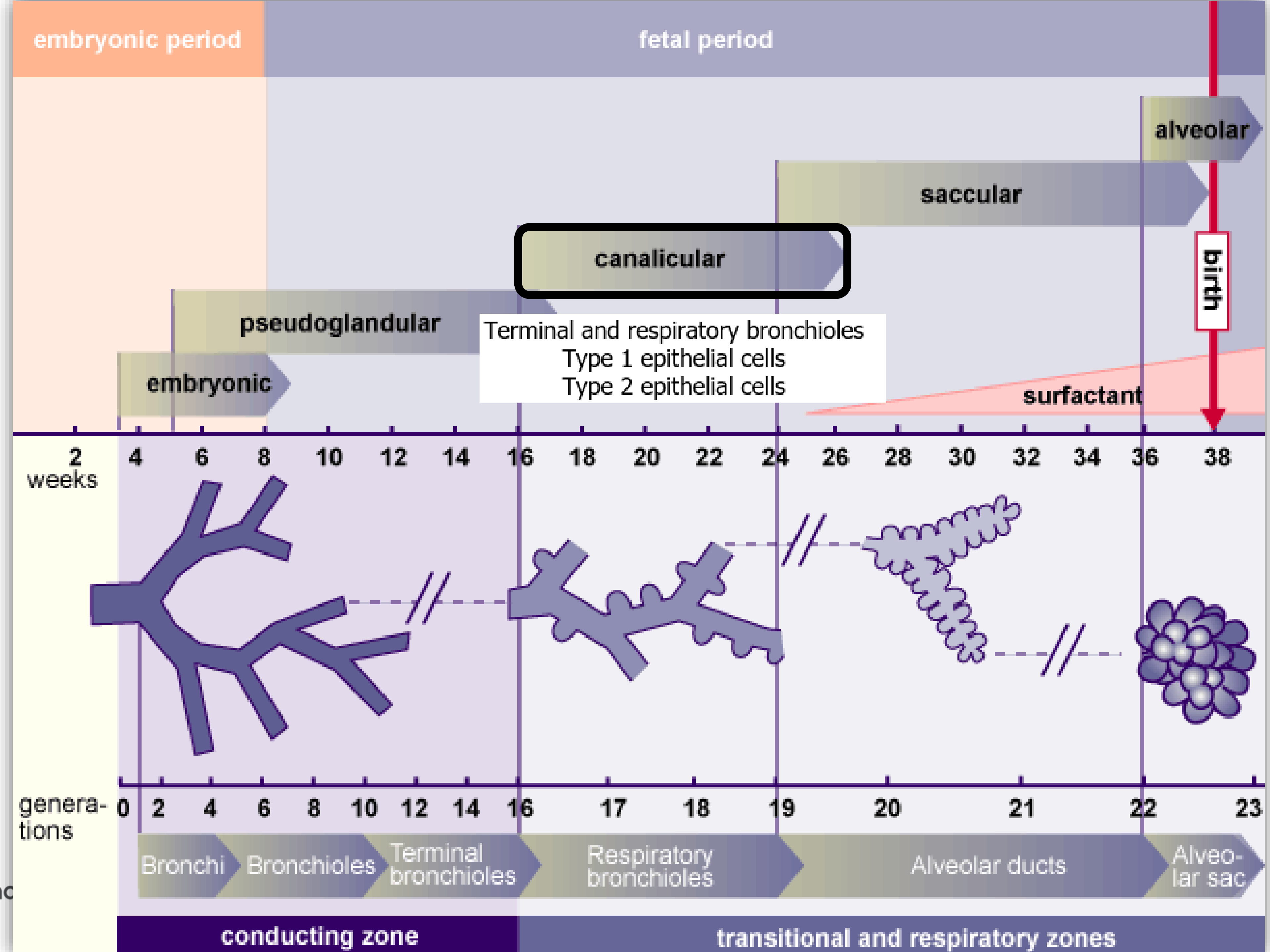
conducting zone
transitional and respiratory zones



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Terminal and respiratory bronchioles
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Type 2 epithelial cells
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Respiratory bronchioles
Alveolar ducts
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conducting zone
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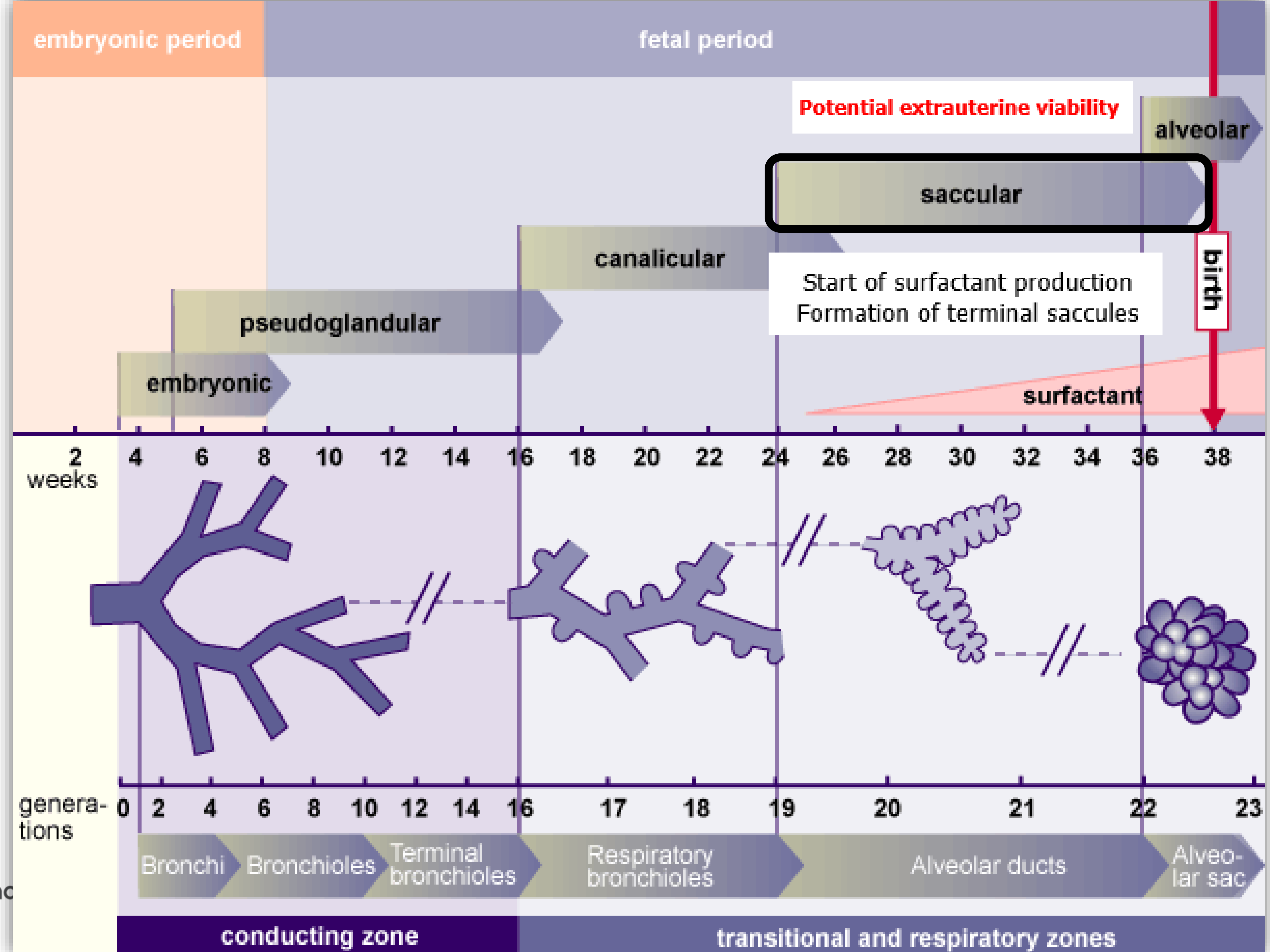

embryonic period
fetal period
Potential extrauterine viability
alveolar
saccular
canalicular
Start of surfactant production
Formation of terminal saccules
birth
pseudoglandular
embryonic
surfactant
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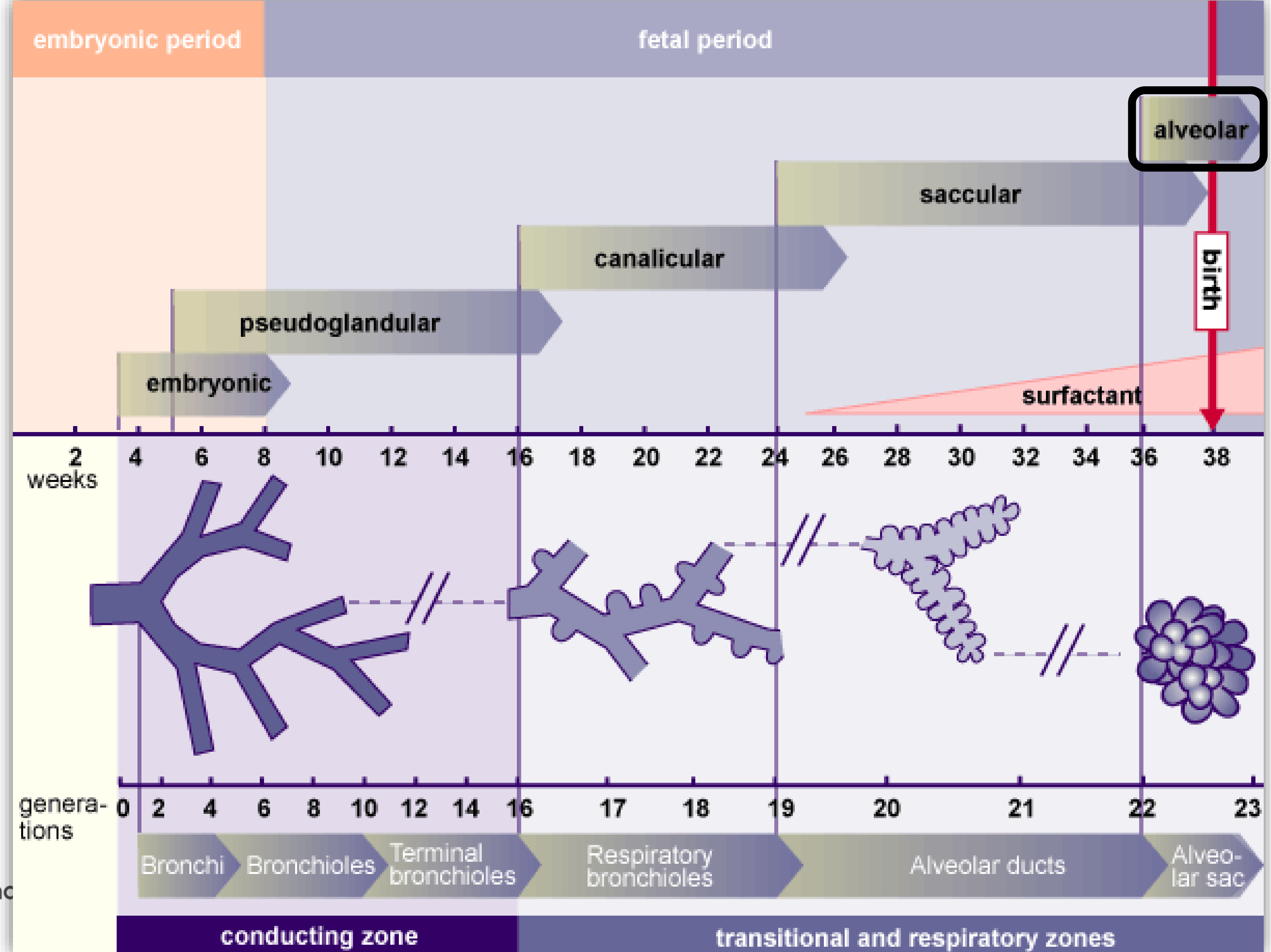
Terminal bronchioles
Respiratory bronchioles
Alveolar ducts
Alveo-lar sac
conducting zone
transitional and respiratory zones


embryonic period
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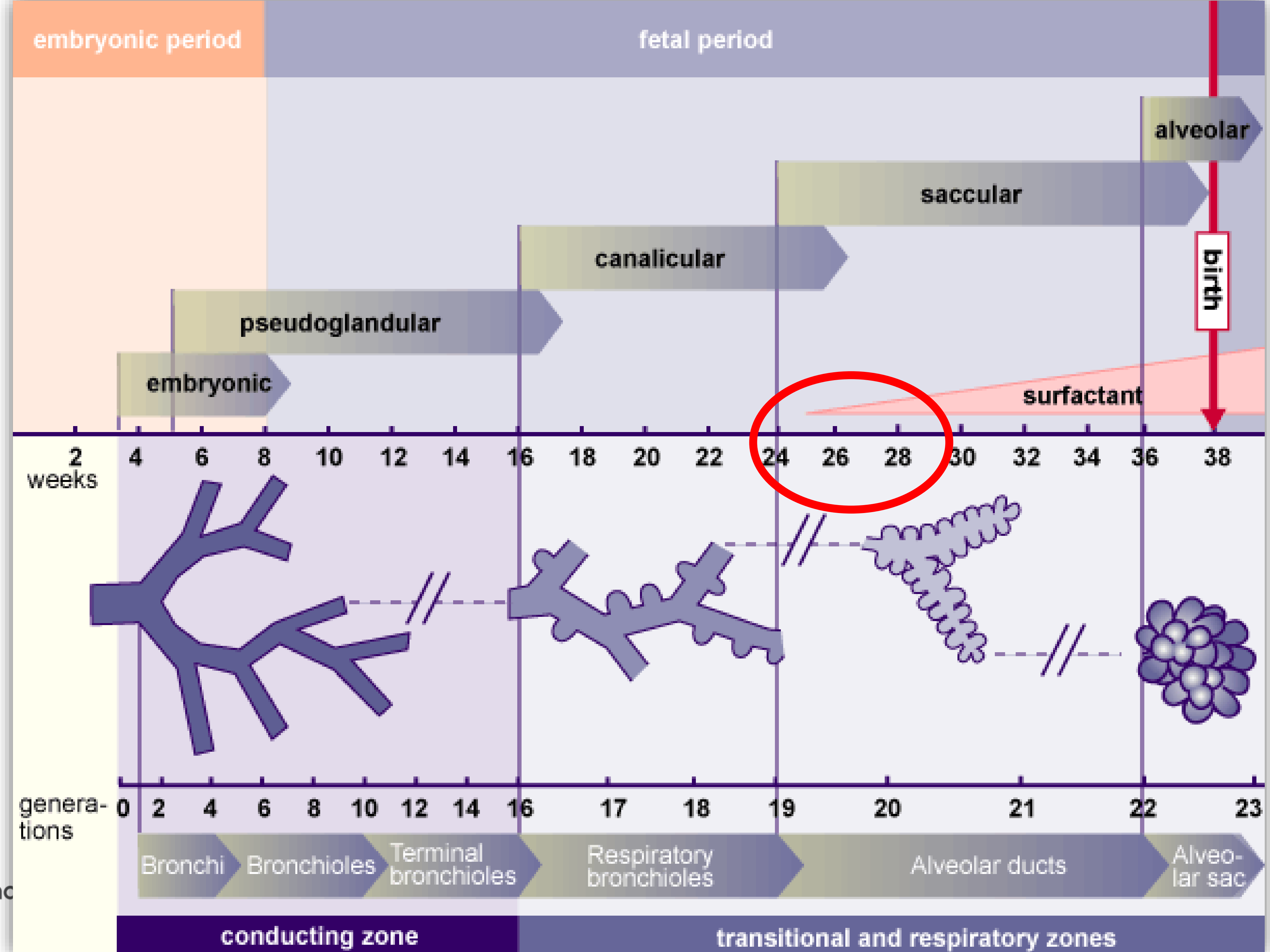

embryonic period
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lar sac
conducting zone
transitional and respiratory zones

Rac

Respiratory Distress Syndrome

- Premature infants are at risk for respiratory failure:
  - surfactant deficiency/inactivation
  - structural immaturity of the lungs

Decreased pulmonary compliance

⬇

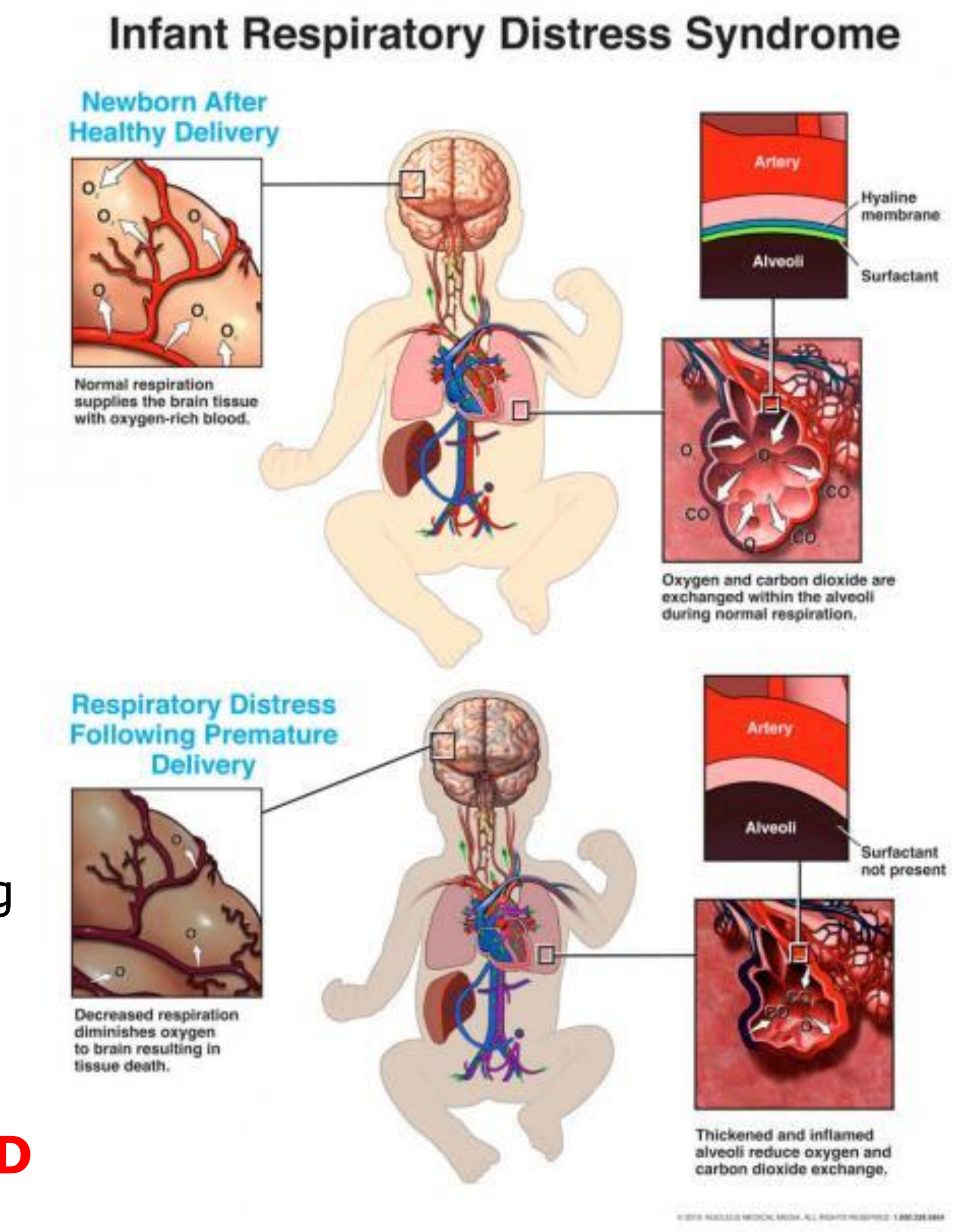
Alveolar Collapse

⬇

Low FRC

- Asymmetric lung disease and lung inflammation
- These factors, with altered lung mechanics, increases the risk of lung injury and air leak syndromes

Lung injury, accentuated in infants with RDS, may predispose the infant to subsequent development of BPD



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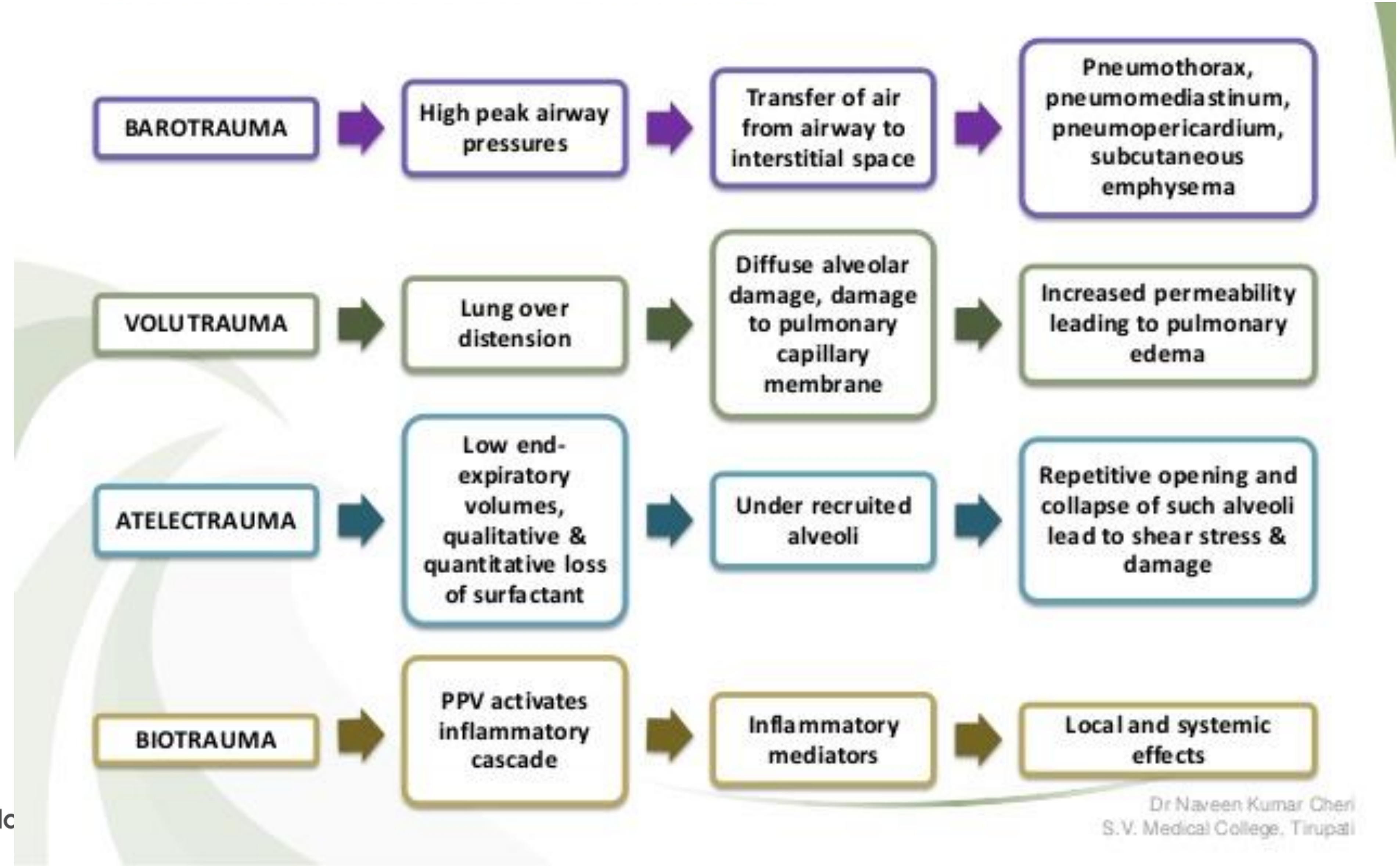
[Newborn Breathing Conditions - Respiratory Distress Syndrome (RDS) | NHLBI, NIH]

Ventilator-Related Factors of VILI



Journal of
Clinical Medicine

Review

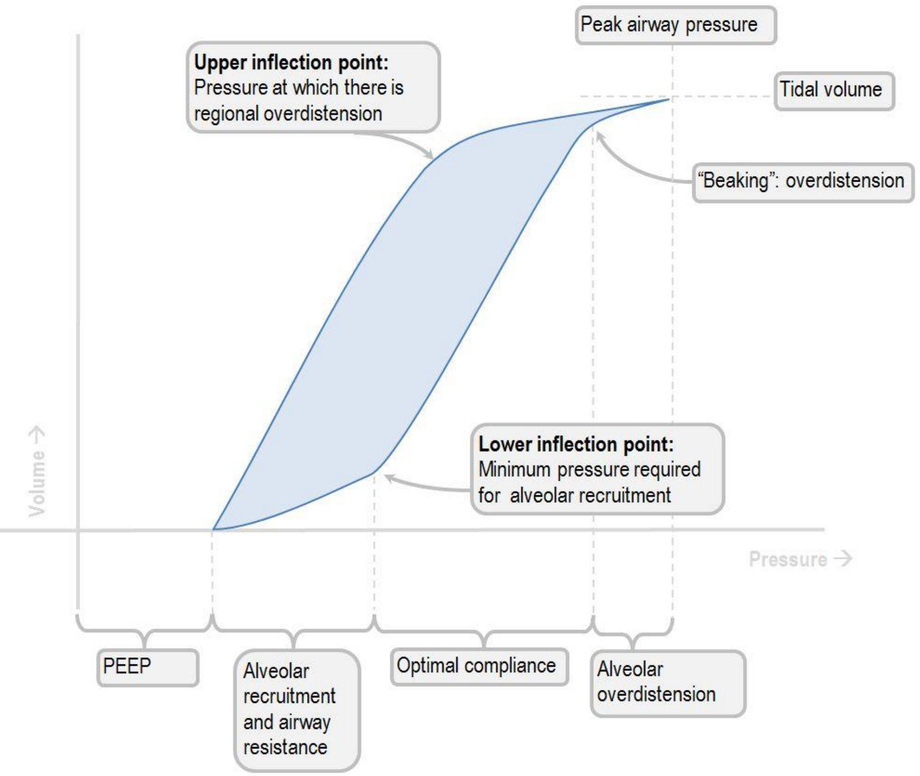
Ventilation-Induced Lung Injury (VILI) in Neonates: Evidence-Based Concepts and Lung-Protective Strategies

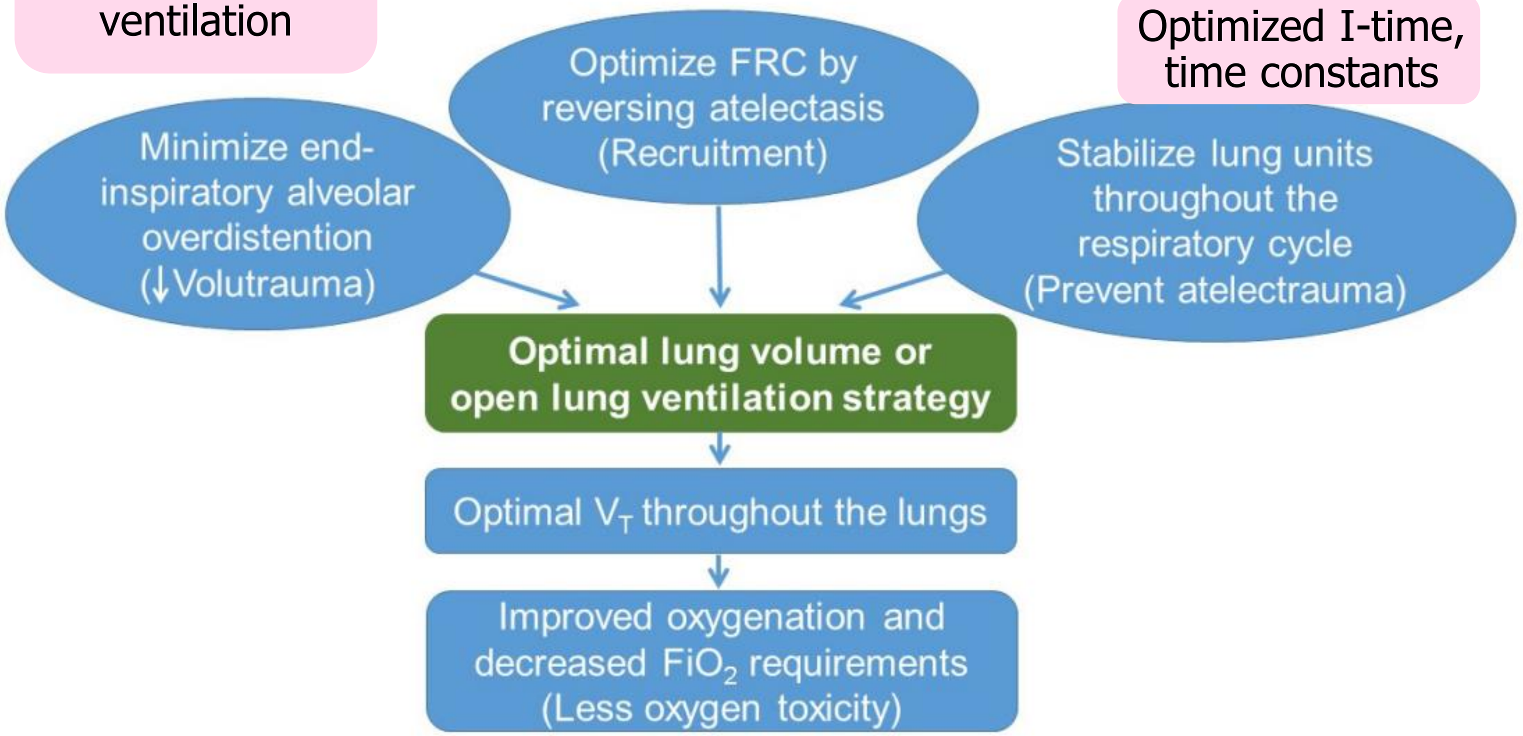
Renjithkumar Kalikkot Thekkeveedu [1], Ahmed El-Saie [2,3], Varsha Prakash [4], Lakshmi Katakam [5] and Binoy Shivanna [5,*]

Safe Vt Delivery, Volume-targeted ventilation

Optimized PEEP

Optimized I-time, time constants





Kalikkot Thekkeveedu R, El-Saie A, Prakash V, Katakam L, Shivanna B. Ventilation-Induced Lung Injury (VILI) in Neonates: Evidence-Based Concepts and Lung-Protective Strategies. J Clin Med. 2022;11(3):557.

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What's More Dangerous: Pressure or Volume?

- **Degree of lung overinflation (too much volume) determines lung injury**
  - Lung collapse and overdistention are major instigators of inflammation in preterm lung *(Dreyfuss 1993, Dreyfuss 1998)*
  - Lower tidal volumes demonstrate significant reduction in lung inflammation *(Hernandez, 1989)*
  - Significant reduction in mortality in low tidal-volume group in adults with ARDS *(ARDSNet, 2000)*
- **In the evolution of Neonatal RDS, lung compliance changes rapidly**
  - Need stable Vt delivery to reduce lung injury
  - Maintaining stable minute ventilation → stable cerebral perfusion → reduces brain damage

Tidal volume, *not inflation pressure,* is the critical factor in VILI

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Cochrane Library

Cochrane Database of Systematic Reviews

Volume-targeted versus pressure-limited ventilation in neonates (Review)

Klingenberg C, Wheeler KI, McCallion N, Morley CJ, Davis PG

- 20 randomized controlled trials
- Volume Targeted Ventilation (VTV) vs. Pressure Limited Ventilation (PLV)
- Infants <44 weeks

Patients that were ventilated with VTV had significantly less:
Death or BPD at 36 weeks PMA
Ventilation days
Pneumothoraces
Hypocarbia
Severe IVIH
Periventricular leukomalacia

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Klingenberg, C.; Wheeler, K.I.; McCallion, N.; Morley, C.J.; Davis, P.G. Volume-targeted versus pressure-limited ventilation in neonates. Cochrane Database Syst. Rev. 2017

Does The Evidence Support **LTV with VTV (PRVC or VG)** Ventilation For Premature Infants with RDS?

The proof is in the pudding!!

Author	Year	Death	BPD	Air Leak	Days of MV	Hypocarbia	IVH/PVL
McCallion, et al. Cochrane Review	2005		↓	↓	↓		↓
Wheeler, et al. Cochrane Review	2005	↓	↓	↓	↓	↓	↓
Peng, et al. MA/SR	2014		↓	↓	↓		↓
Klingenberg, et al. Cochrane Review	2017		↓	↓	↓	↓	↓

CONGRESS 2024

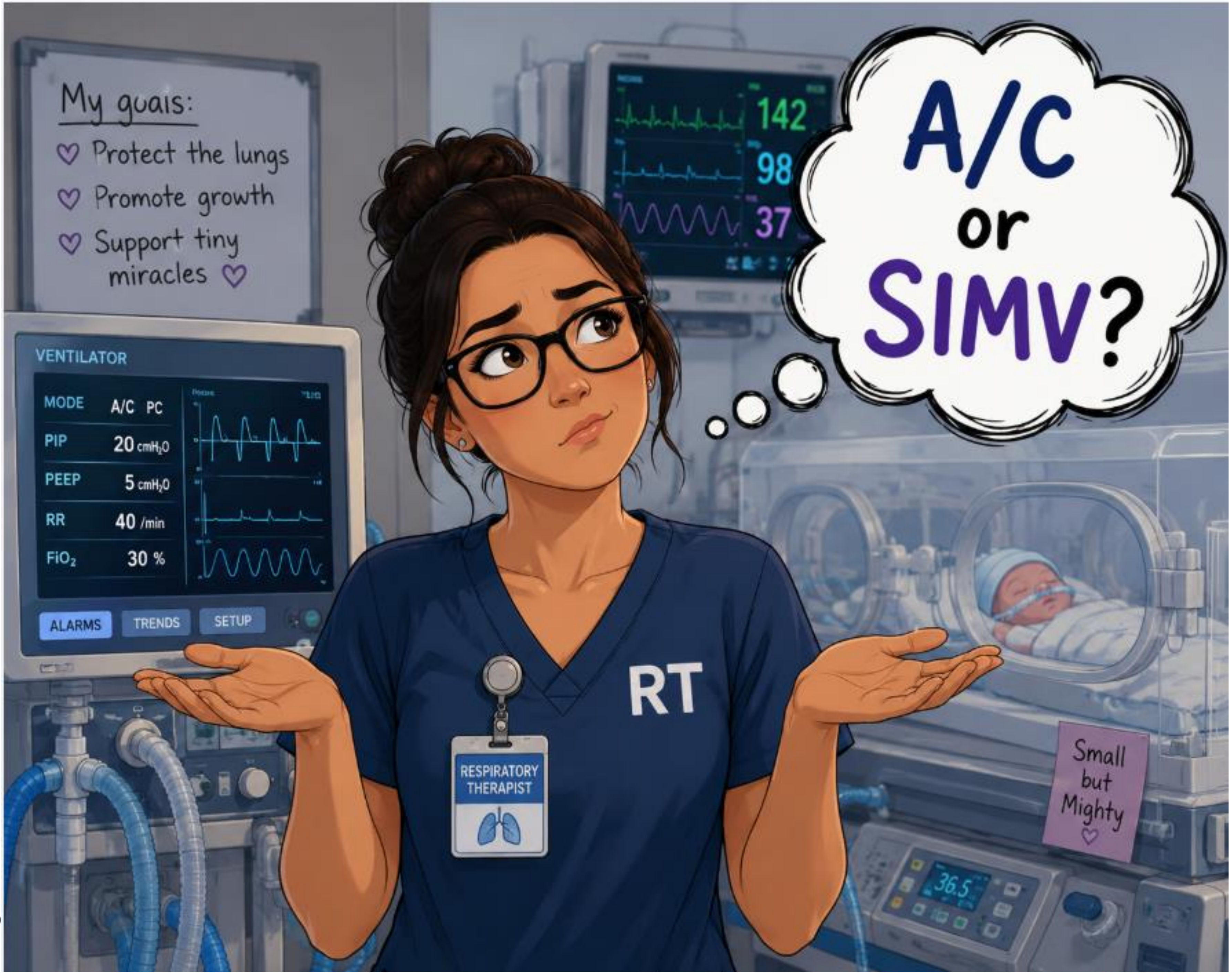
*when compared with pressure-limited modes

Source: La Vita, C., "Volume-Targeted Modes of Mechanical Ventilation in Neonates", AARC Congress 2024

Does The Evidence Support **HFJV** For Premature Infants with RDS?

Author	Year	Death	BPD	Air Leak	IVH/PVL	Gas Exchange
Cochrane Review HFJV (*elective*) vs CMV (Wiswell, 1996) (Keszler, 1997) (Carlo, 1990)	2000		★			
Cochrane Review HFJV (*rescue*) vs CMV (Keszler, 1991)	2006 2015					
Plavka Crossover Study	2006					★
Cochraine Review HFJV vs. HFOV (0 studies)	2016					

Source: Lamorena, E., "Non-Conventional Modes In NeoPed: What Really Matters?", AARC Congress 2025


My goals:
Protect the lungs
Promote growth
Support tiny miracles
142
98
37
A/C or SIMV?
VENTILATOR
MODE A/C PC
PIP 20 cmH2O
PEEP 5 cmH2O
RR 40 /min
FiO2 30 %
ALARMS
TRENDS
SETUP
RT
RESPIRATORY THERAPIST
Small but Mighty
36.5

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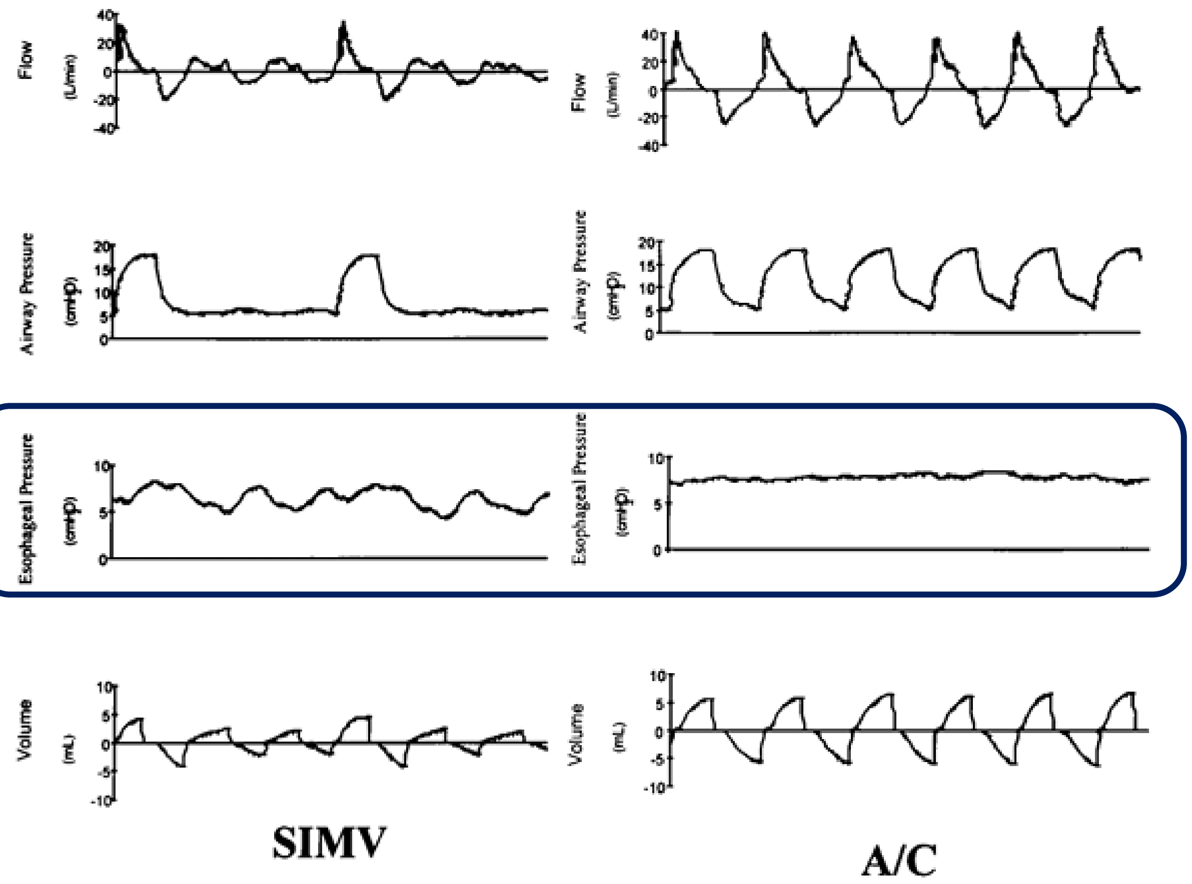
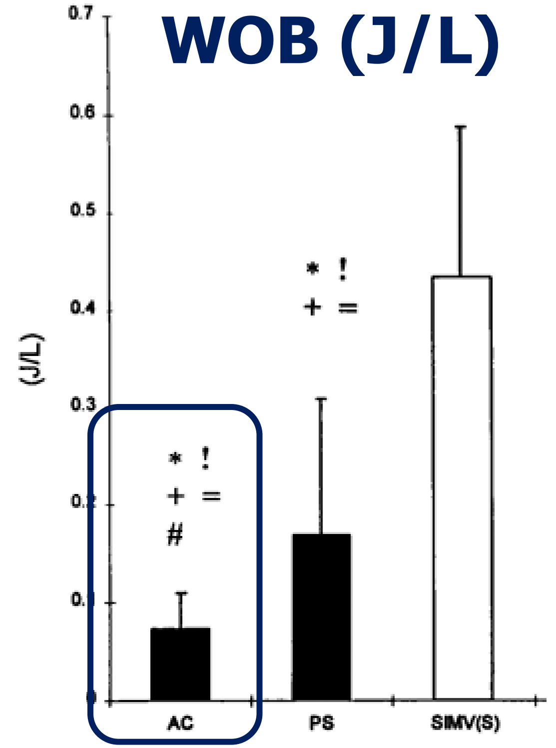
Effort and work of breathing in neonates during assisted patient-triggered ventilation

Munir Kapasi, MD; Yuji Fujino, MD; Max Kirmse, MD; Elizabeth A. Catlin, MD;
Robert M. Kacmarek, PhD, RRT, FCCM





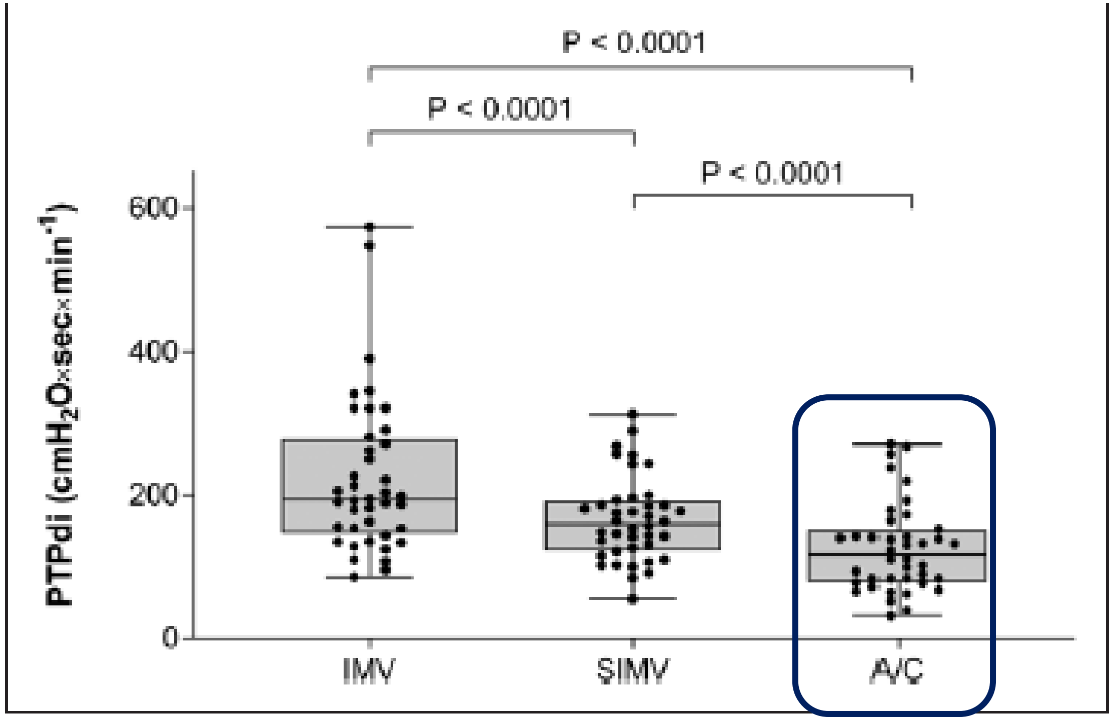
- Asynchrony can be avoided by the use of assisted, A/C
- AC/PC results in the least effort and work of breathing for clinically stable neonates

Kapasi, Munir MD; Fujino, Yuji MD; Kirmse, Max MD; Catlin, Elizabeth A. MD; Kacmarek, Robert M. PhD, RRT FCCM. Effort and work of breathing in neonates during assisted patient-triggered ventilation. Pediatric Critical Care Medicine 2(1):p 9-16, January 2001.

Neonatal Intensive Care

Work of Breathing in Mechanically Ventilated Preterm Neonates*

Aggeliki Vervenioti, MD; Sotirios Fouzas, MD, PhD; Sotirios Tzifas, MD;
Ageliki A. Karatza, MD, PhD; Gabriel Dimitriou, MD, PhD



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Vervenioti, Aggeliki MD; Fouzas, Sotirios MD, PhD; Tzifas, Sotirios MD; Karatza, Ageliki A. MD, PhD; Dimitriou, Gabriel MD, PhD. Work of Breathing in Mechanically Ventilated Preterm Neonates*. Pediatric Critical Care Medicine 21(5):p 430-436, May 2020

Cochrane Library

Cochrane Database of Systematic Reviews

Synchronized mechanical ventilation for respiratory support in newborn infants (Review)

Greenough A, Rossor TE, Sundaresan A, Murthy V, Milner AD

Analysis 4.1. Comparison 4: ACV vs SIMV, Outcome 1: Duration of weaning (hours)

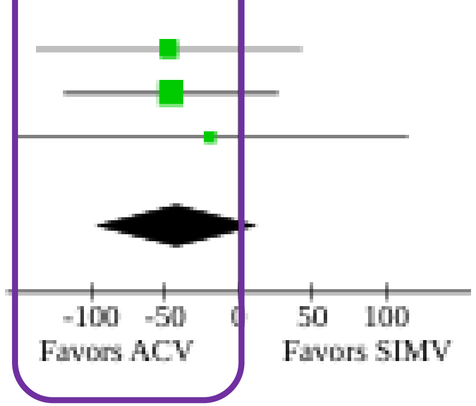
Study or Subgroup	ACV Mean	ACV SD	ACV Total	SIMV Mean	SIMV SD	SIMV Total	Weight	Mean Difference IV, Fixed, 95% CI
Chan 1994	77.6	102.3	20	124.9	178	20	33.4%	-47.30 [-137.28 , 42.68]
Dimitriou 1995a	53	95	20	99	135	20	51.6%	-46.00 [-118.35 , 26.35]
Dimitriou 1995b	118	265	20	137	153	20	15.0%	-19.00 [-153.11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

Heterogeneity: $Chi^2 = 0.14$, $df = 2$ ($P = 0.93$); $I^2 = 0\%$

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

Test for subgroup differences: Not applicable

Mean Difference IV, Fixed, 95% CI



Greenough A, Rossor TE, Sundaresan A, Murthy V, Milner AD. Synchronized mechanical ventilation for respiratory support in newborn infants. Cochrane Database Syst Rev. 2016

Journal of Perinatology 2005; 25:638–642

Effect of Volume Guarantee Combined with Assist/Control vs Synchronized Intermittent Mandatory Ventilation

Kabir Abubakar, MD
Martin Keszler, MD

Crossover, randomized controlled trial
AC/VG vs SIMV-VG
12 patients

Table 3 Heart Rate, Respiratory Rate and Oxygenation

		AC+VG	SIMV+VG	*p*-value
Heart rate (beats/minute)	Mean±SD	148±5	161±7	$p<0.0001$
	Variance	25	46	$p<0.0001$
Respiratory rate (breaths/minute)	Mean ±SD	55.1±6.4	65±8	$p<0.0001$
	Variance	44.0	70.0	$p<0.01$
Oxygen saturation (%)	Mean ±SD	95±2	91±3	$p<0.0001$
	Variance	3	12	$p<0.0001$

Table 2 Ventilator Variables

		AC+VG	All SIMV breaths	SIMV+VG machine breaths	SIMV spontaneous breaths	*p*-value
PIP (cmH_2O)	Mean±SD	15±4.1*	14±4.8	17±2.9*		$p<0.001$*
	Variance	17.9*	24.4	9.5*		$p<0.001$*
MAP (cmH_2O)	Mean±SD	8.6±1.8*	8.2±2	9.3±1.6*		$p<0.004$*
	Variance	3.4	4.0	2.7		$p<0.001^{\dagger}$
Exhaled tidal volume (ml)	Mean±SD	5.2±0.5	4.9±2.0	5.1±1.8	3.2±1.8	$p<0.001^{\dagger}$
	Variance	0.3	4.4	3.4	3.5	$p<0.0001^{\ddagger}$
Minute volume (ml)	Mean±SD	328±50	319±78			NS
	Variance	348	652			$p<0.001$

Infants supported by PC-SIMV/VG had greater RR, HR and WOB and lower SpO_2, than PC-AC/VG
AC resulted in more consistent tidal volumes at lower total RR and PIPs than SIMV

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Abubakar K, Keszler M. Effect of volume guarantee combined with assist/control vs synchronized intermittent mandatory ventilation. J Perinatol. 2005

We're all using A/C VTV, right?

Surveys of Neonatal Ventilation Practices

United Kingdom

Acta Pædiatrica ISSN 0803–5253

REGULAR ARTICLE

Survey of neonatal respiratory support strategies

Atul Sharma, Anne Greenough (anne.greenough@kcl.ac.uk)
King's College London, MRC-Asthma Centre, Division of Asthma, Allergy and Lung Biology, London, UK

A/C: 4%
VTV: 5%

(Sharma, 2007)

Europe

The Journal of Pediatrics • www.jpeds.com

ORIGINAL ARTICLES

Ventilation Practices in the Neonatal Intensive Care Unit: A Cross-Sectional Study

Anton H. van Kaam, MD, PhD, Peter C. Rimensberger, MD, Dorine Borensztajn, MD, and Anne P. De Jaegere, MD on behalf of the Neovent Study Group*

A/C: 31%
VTV: 9%

(van Kaam, 2010)

Australia, New Zealaned, Nordic Countries

An international survey of volume-targeted neonatal ventilation

Claus Klingenberg,[1–3] Kevin I Wheeler,[1,4,5] Louise S Owen,[1,4] Per I Kaaresen,[2,3] Peter G Davis[1,4,6]

A/C: 84%
VTV: 50%

(Klingenberg, 2010)

What about the United States?

Survey of Ventilation Practices in the Neonatal Intensive Care Units of the United States and Canada: Use of Volume-Targeted Ventilation and Barriers to Its Use

Ashish Gupta, MD[1] Martin Keszler, MD[1]

Canada 81%

US 39%

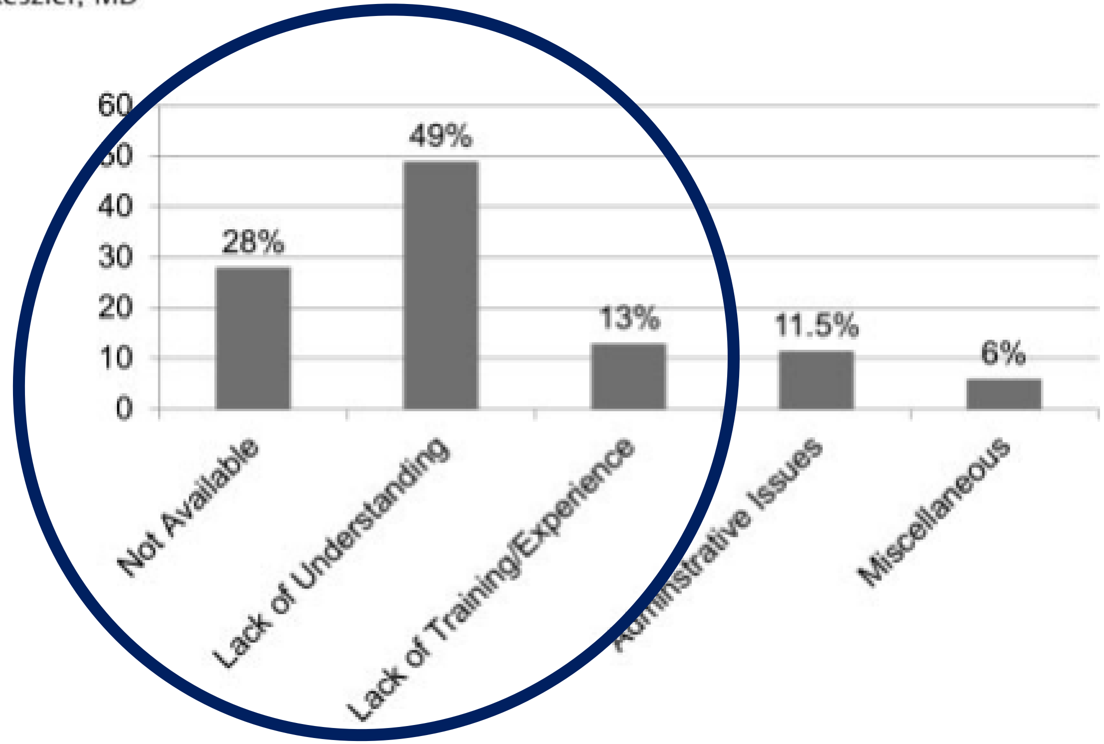

Fig. 1 Reasons for not using volume-targeted ventilation.

Gupta A, Keszler M. Survey of Ventilation Practices in the Neonatal Intensive Care Units of the United States and Canada: Use of Volume-Targeted Ventilation and Barriers to Its Use. Am J Perinatol. 2019 Apr;36(5):484-489.

Review:

Fundamentals of Mechanical Ventilation

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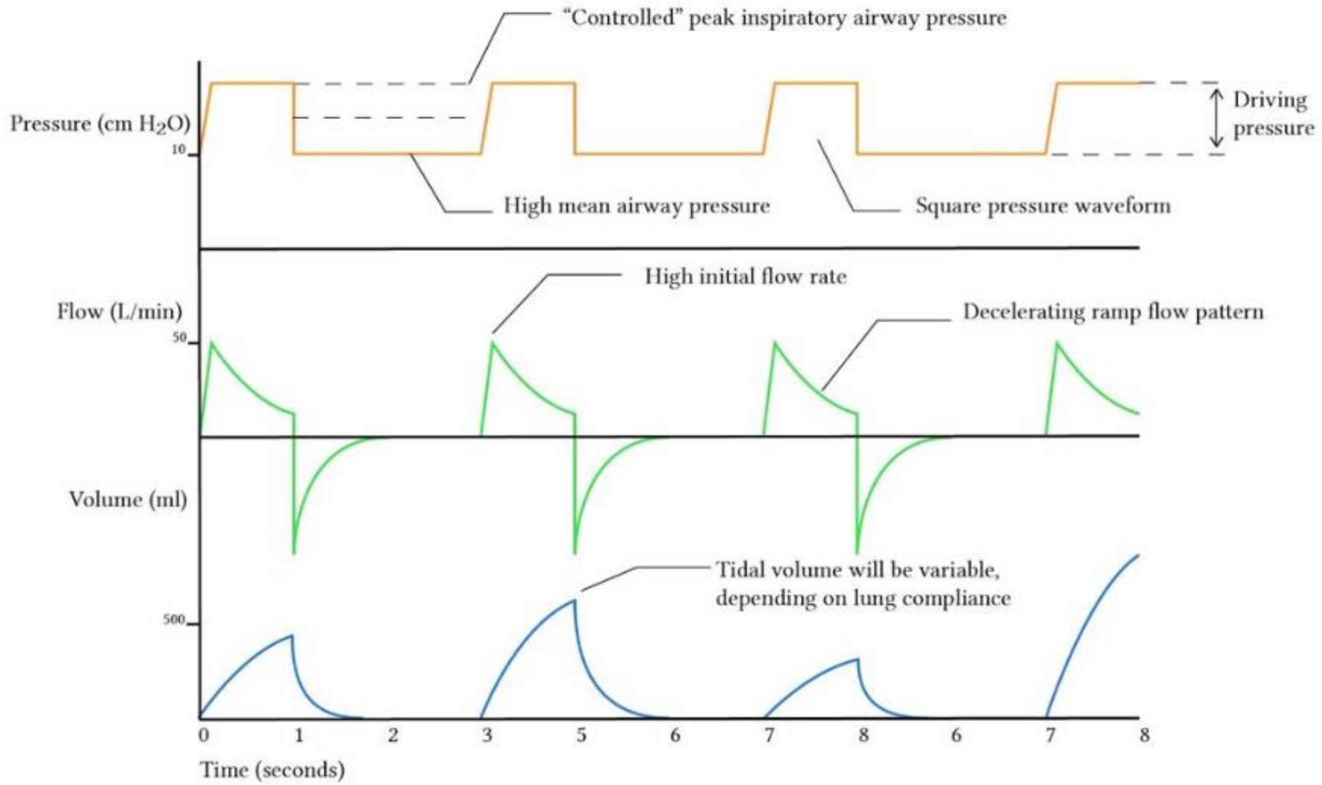
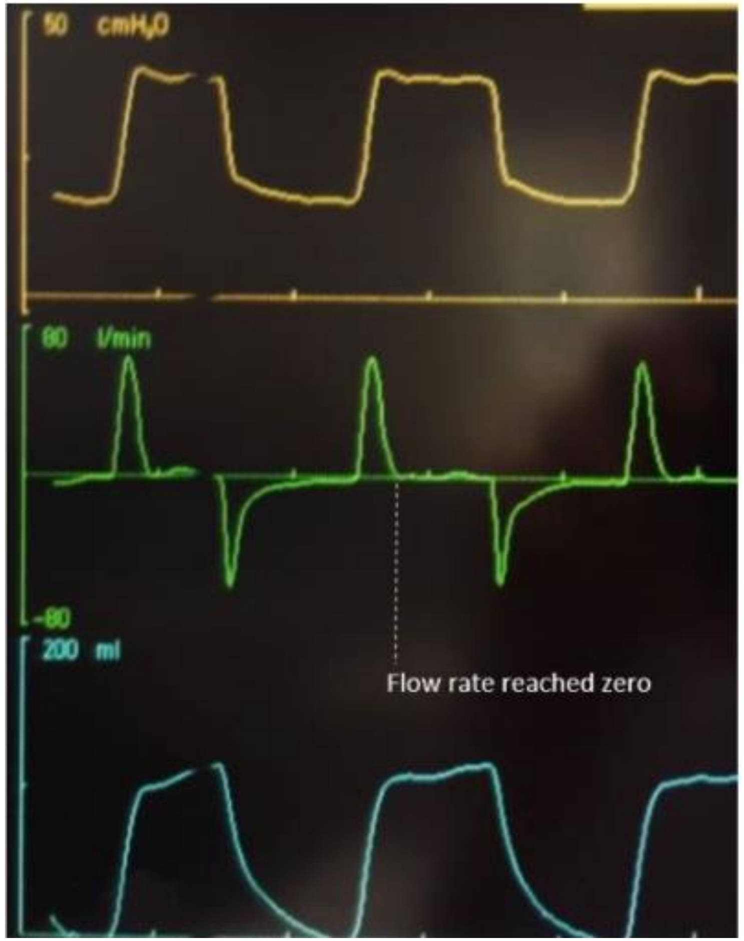
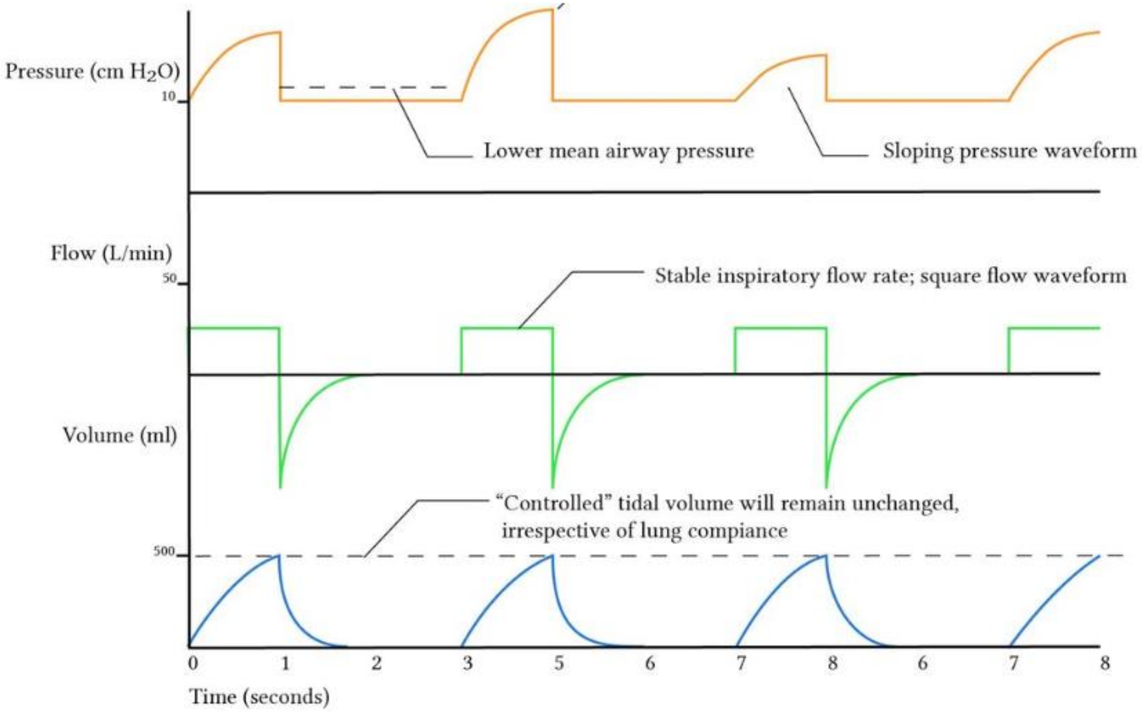
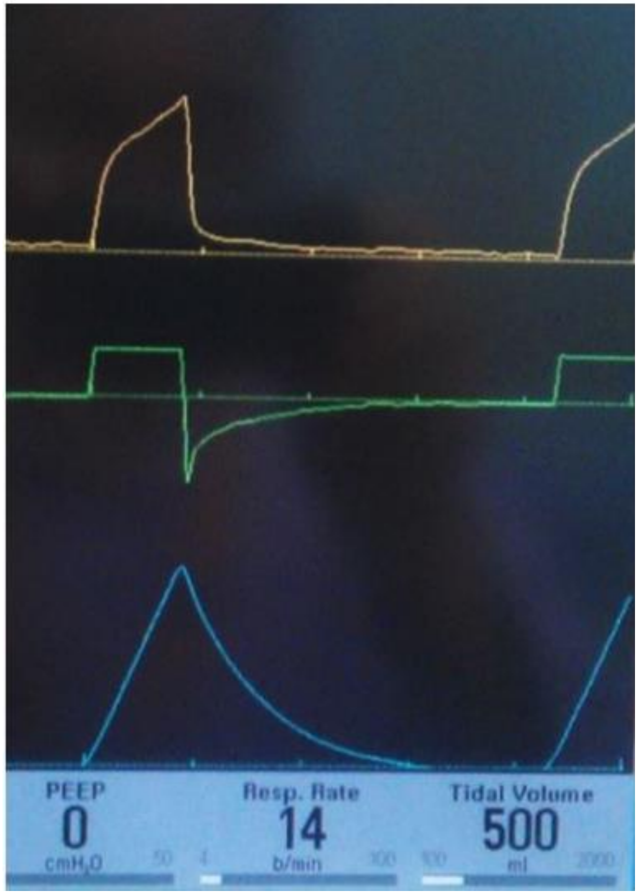
Control Variable: Pressure





Control Variable: Volume





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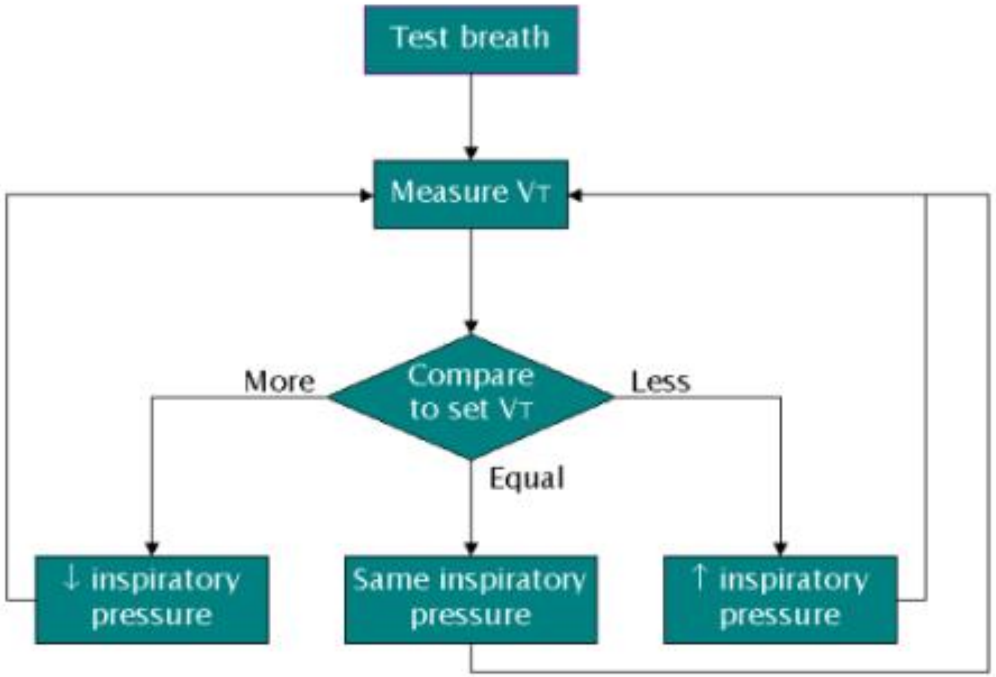
Adaptive PC Modes

- **What are "Adaptive PC Modes"?**
  - Pressure controlled, Volume-targeted mode
  - Measure exhaled Vt, adjusts flow/pressure until target Vt is met
  - Different names:
    - Pressure Regulated Volume Control / PRVC (Servo)
    - Volume Guarantee (VG) / Autoflow (Draeger)
    - VC+ (PB980)

- **Why?**
  - Volume Control: Delivers set Vt, flow, I-time; can ensure appropriate tidal volumes
    - they are flow limited – may be uncomfortable for patient
    - Can lead to high ventilating pressures
    - Does not function well with leaks
  - Pressure Control: Limits/controls pressures
    - Variable tidal volume / minute ventilation delivery
  - Adaptive PC Modes:
    - Consistent tidal volume delivery
    - Meet flow demand
    - Maintains safe pressure limits



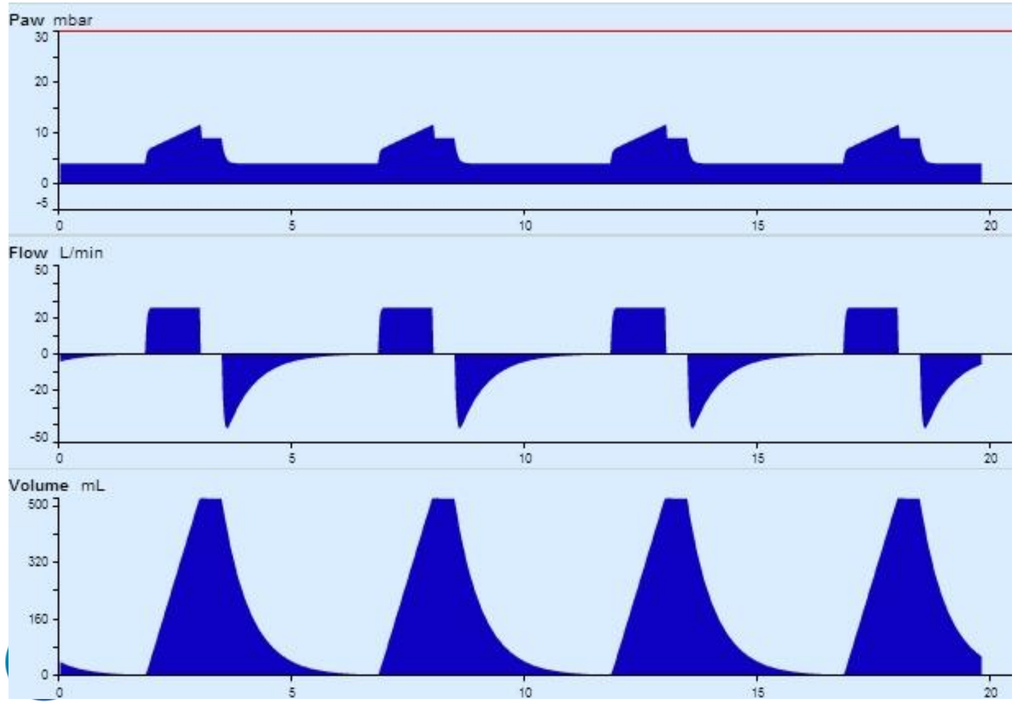
Adaptive Ventilation Modes (VG, PRVC, VC+)
Potential Problems

- **Patients with high respiratory drives**
  - Vent can't distinguish between improved compliance/resistance and the patient pulling flow, so it "weans" the patient to very low inspiratory pressure
  - Patient has to work harder → increased WOB
- **Patients demanding higher tidal volumes**
  - Most modern ventilators have floating valves, allowing patient to pull more volume if they want it
  - Vent will decrease delivered pressures
- **What can we do to protect our patients?**
  - Set appropriate alarm limits
  - If PIPs are getting very low (<10), ***investigate!***

A/C vs SIMV

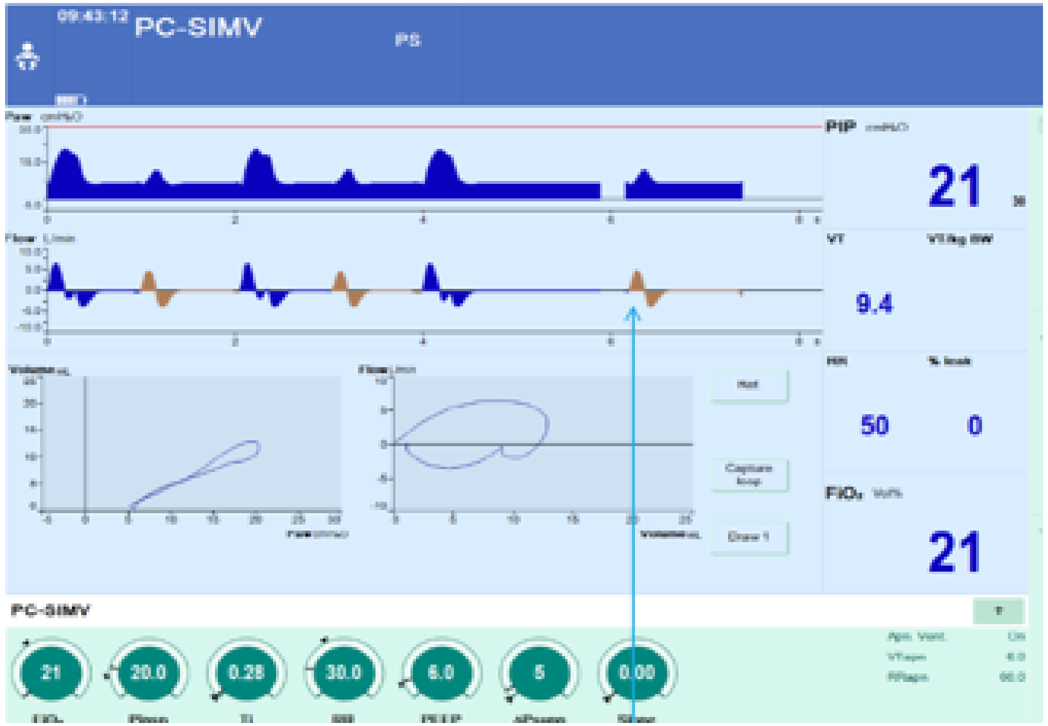
Assist Control

- Machine breaths only
  - Mandatory breaths are given at a set frequency.
  - The patient is able to trigger additional machine breaths between the set frequency (***Assisted breaths***)
  - Clinician sets a tidal volume or pressure: **Every breath will be the same.**



Synchronized Intermittent Mandatory Ventilation

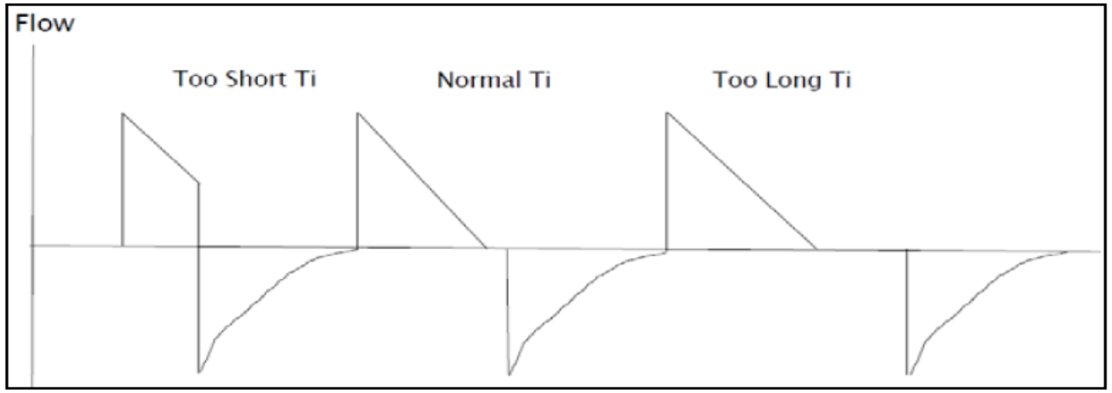
- Machine and Patient breath types are available
- Machine
  - Mandatory breaths are given at a clinician set frequency.
  - Assisted breaths are given inside a "sync" window.
- Spontaneous breaths are allowed between mandatory breaths.
  - Supported breaths are available if Pressure Support is added (SIMV + PSV)

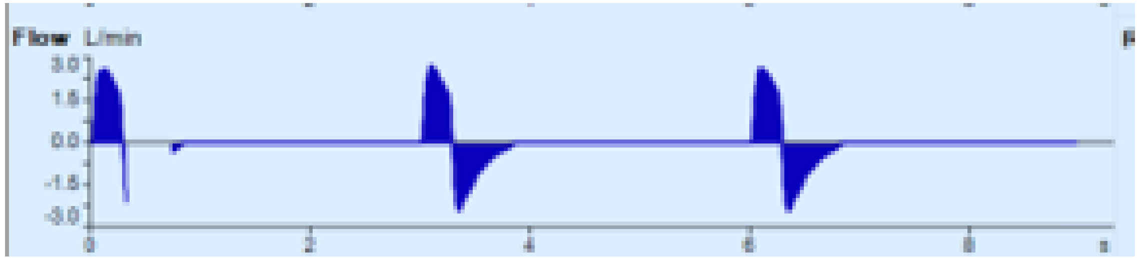


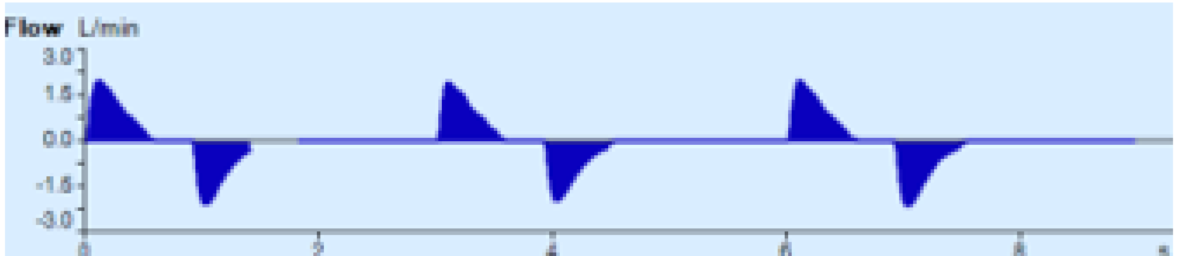
Setting I-time

	I-time range	Considerations
< 28 weeks	0.25-0.35 sec	Short time constant
28-32 weeks	0.3-0.35 sec	Balance between adequate Vt and avoid breath stacking
32 – 37 weeks	0.35-0.40 sec	Monitor for asynchrony
>37 weeks	0.40-0.50 sec	Longer I-time may improve oxygenation in stiff lungs
BPD/CLD	0.5-0.8 sec	Longer I-time may improve oxygenation in stiff lungs

Assess flow-time scalar to assess for appropriate inspiratory time



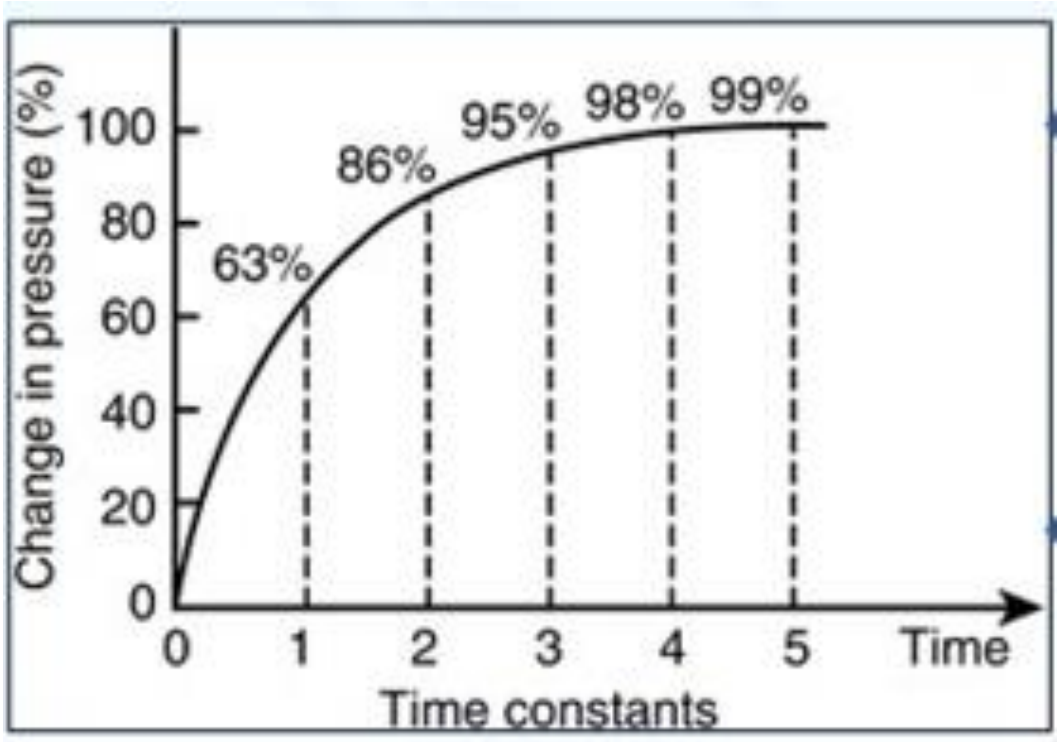




Time Constants

- The time required for the lungs to fill or empty by 63% during passive breathing.
- Helps to determine frequency, I-time, and E-time
- Need ***minimum of 3 time constants*** to assure that 95% of lungs have emptied

Compliance x Resistance



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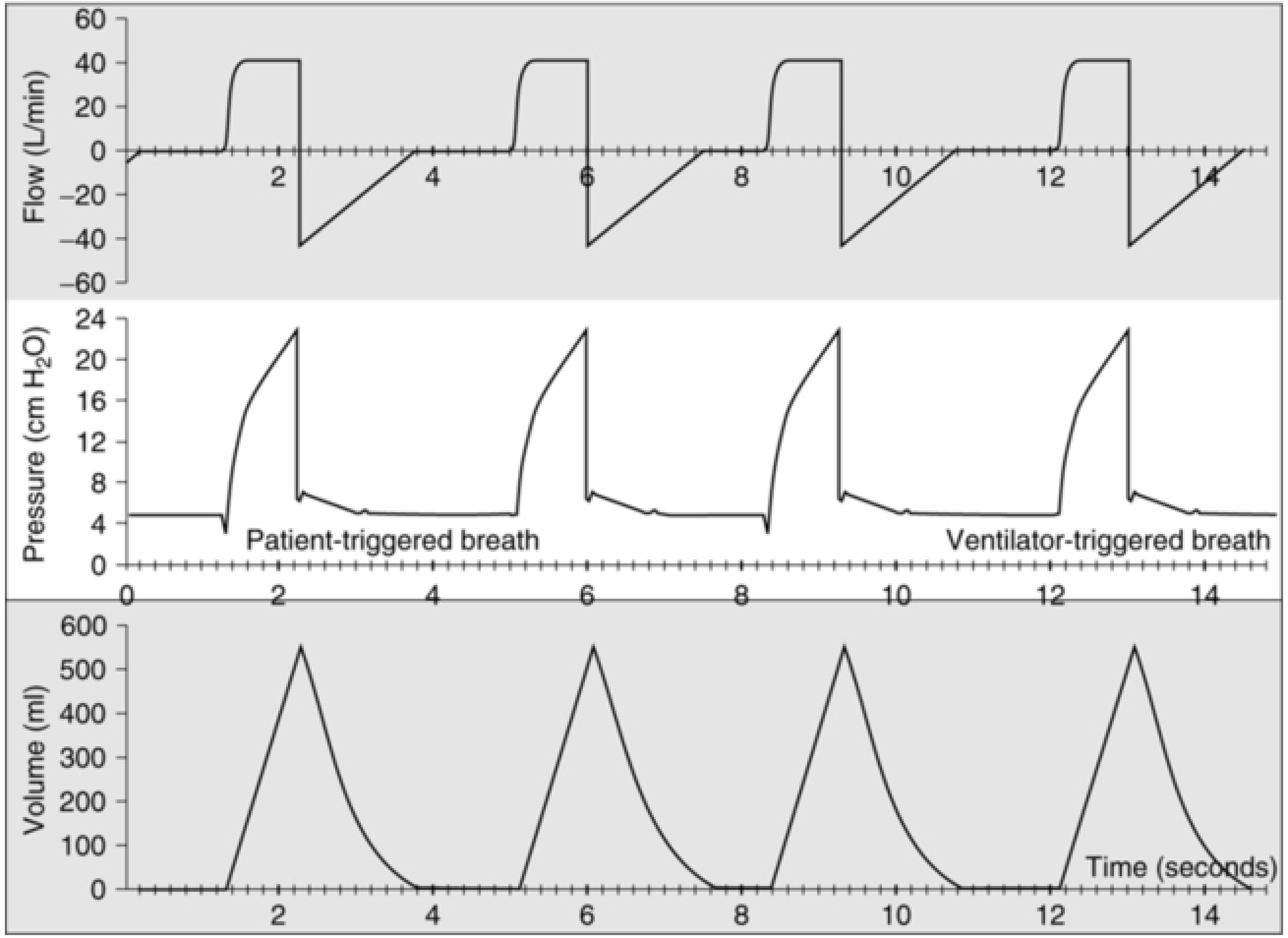
Considerations with Assist Control



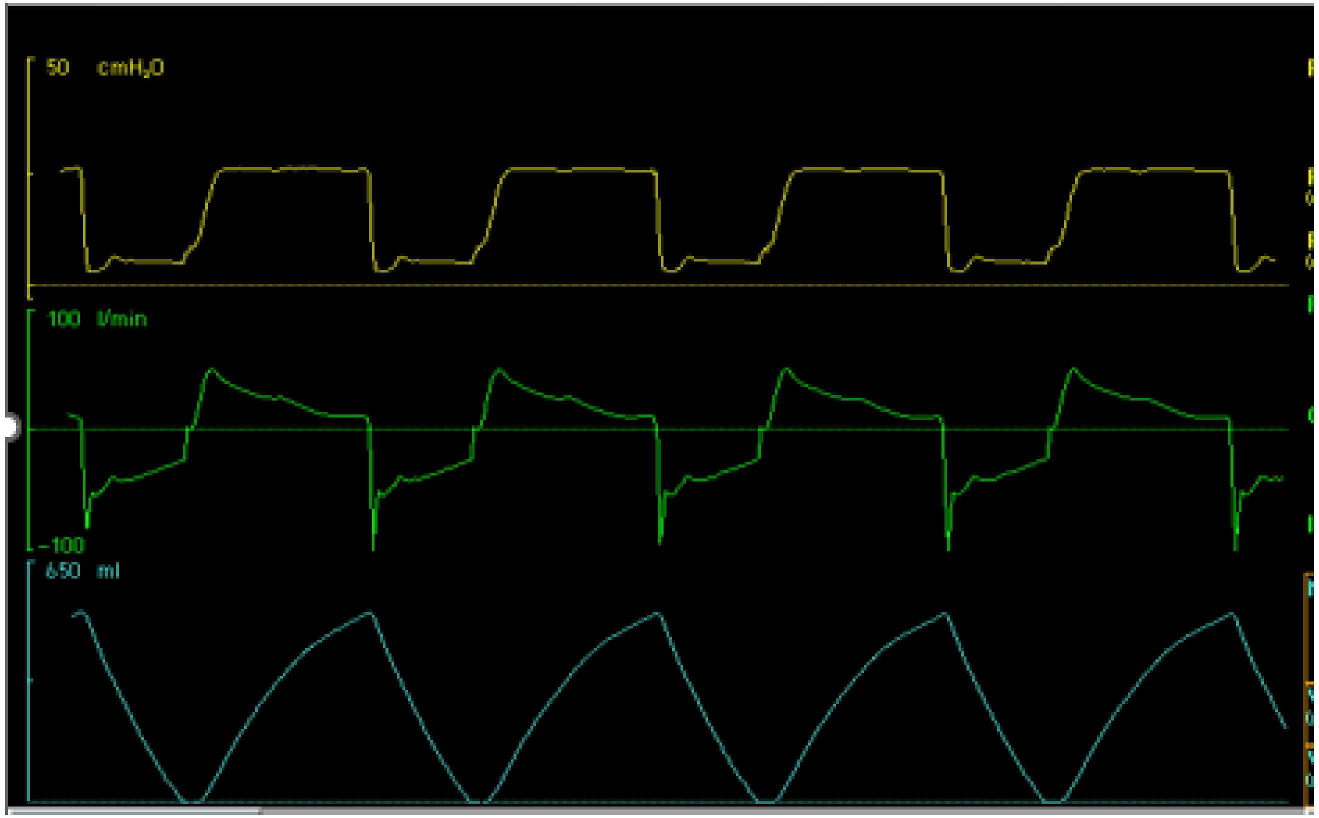
- Settings:

RR=30
I-time=0.5s
PIP=24, PEEP=+5

- I:E ratio?

TCT=60/30=2s
I-time=0.5s
E-time=1.5s
I:E=1:3 ratio

Considerations with Assist Control



What happens if the patient wakes up and starts breathing with RR=60?

- I:E Ratio

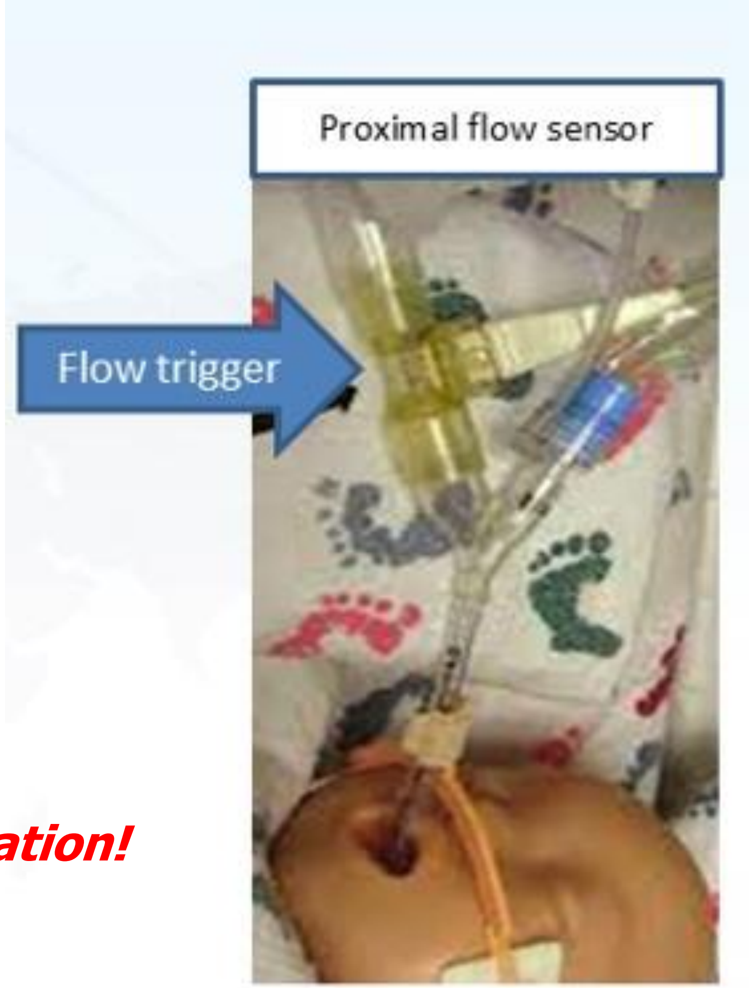
TCT=1s
I-time=0.5s
E-time=0.5s
I:E=1:1 ratio

Importance Of Proximal Flow Sensor

- Pros:
  - *ensures lung protective ventilation for premature infants!
  - Pneumotach that senses very small changes in flow
  - Enhanced triggering
  - Precise tidal volume measurement
  - Can reduce WOB, days on vent, ICU stay, weaning times

- Cons:
  - Secretions/condensation affect management
  - deadspace

- **CAUTION:** ***Not hearing alarms does not mean improved ventilation!***
  - It means issues are not being recognized or addressed
  - No longer receiving benefit of lung protective ventilation



Which Mode Should We Use?
A/C vs. SIMV vs. PSV

**PC-AC/VG: Acute Phase of lung disease

- AC is preferred, rather than SIMV, so that every breath has a V_T target and consistent inspiratory time during volume guarantee.
- ***A/C associated with lower WOB and more consistent Vt /minute ventilation***

PC-SIMV/VG – Hyperinflation/Air Trapping

- SIMV should be considered when hyperinflation and air-trapping is present
  - Ensure I-time and E-time management optimized on A/C first before switching

PC-PSV/VG – Weaning

- PC-PSV/VG is generally used during the weaning phase (i.e., FiO_2<0.4) or when patients develop significant dysynchrony during PC-AC/VG.
  - Patients must have an adequate respiratory drive when using this mode.
  - Cautionary use in babies with low lung compliance and problems oxygenating
  - The clinician must watch the spontaneous inspiratory time

TABLE 54.12 **Suggested Initial Ventilator Settings in Different Neonatal Conditions**

Condition	Breath Sequence	Weight or Age	Tidal Volume (mL/kg)	Initial PIP Limits (cm H_2O)	PEEP (cm H_2O)	Mandatory Rate (breaths/min)	Inspiratory Time (s)
Premature Infants (RDS and other)	Assist Control in the acute phase of RDS, PC-IMVa,s *(VC Plus, PRVC, VG)*	<1.0 kg	5-7*	26-28	5-7	40-60	0.25-0.3
		1.0-1.5 kg	5-6	22-26	5-8	40-50	0.3-0.35
		>1.5 kg	5-6	20-24	5-8	35-50	0.3-0.4
Term Newborn (Sepsis, PPHN, other)	TBD	3.0-4.0 kg	5-6	20-24	5-6	20-30	0.3-0.45
BPD Moderate	PC-IMV*a*, PC-IMV*s*, CSV*a*	>3-4 weeks, requires ↑ VT/PC levels for improved CO_2 and WOB	7-8	20-35	6-10	15-30 (with PSV)	0.35-0.45
BPD Severe	PC-IMV*a*, PC-IMV*s*, CSV*a*	>4 weeks (established BPD)	8-10	25-40 (↑ PEEP+V_T requires higher PIP limit)	7-15 (higher PEEP may be considered for dynamic airway collapse)	12-30 (with PSV) A slower rate optimizes exhalation with larger V_T	0.4-0.65 Higher Ti optimizes ventilation distribution
Congenital Diaphragmatic Hernia	PC-CMV*a (acute phase)*, PC-IMV*s*	3.0-4.0 kg	4-5	22-26	5-6	40-60	0.3-0.45
Meconium Aspiration Syndrome	PC-IMV*a*, PC-IMV*s*, CSV*a*	3.0-4.0 kg	4.5-6	28-30	4-8	30-60	0.25-0.45

If tachypnea persists and WOB is high, consider an increase in ↑ V_T (0.5 to 1 ml/kg) or PC even if the $PaCO_2$ and pH are normal. Tachypnea and ↑ WOB may indicate higher PEEP requirements. If the pressure limit must be increased substantially or repeatedly, verify that the tidal volume measurement is accurate (assess chest rise, obtain ABG), and if valid, seek the cause of the change in lung mechanics (examine the patient, obtain chest radiograph. Most infants can be extubated when they consistently maintain V_T at or above the target value with delivered PIP <10 to 12 cm H_2O (<12 to 15 cm H2O in infants >1 kg), with FiO_2 <0.35 and sustained respiratory effort.

*A higher volume target may be required based on proportionally higher instrumental deadspace from the ET tube and proximal flow sensor

*A higher volume target may be required based on proportionally higher instrumental deadspace from the ET tube and proximal flow sensor

[1]PC-CMV*a* (PC-continuous mandatory ventilation with adaptive volume-targeting, e.g., volume guarantee or SIMV PRVC)

[2] PC-IMV*a* (PC-Intermittent Mandatory Ventilation with adaptive volume-targeting)

[3] PC-IMV*s* (PC-Intermittent Mandatory Ventilation with set-point targeting, aka Pressure Control)

[4] CSV*a,s* (CSV-continuous spontaneous ventilation; *a*-adaptive volume-targeting, e.g., PSV-volume guarantee, volume support; *s*-setpoint, e.g., pressure support ventilation

Updated on 1/23

Rady Children's Health

Sammour, Iman, and Robert M. DiBlasi. "Neonatal and Pediatric Respiratory Care." *Egan's Fundamentals of Respiratory Care*, ch. 54, 2025.

Dx or Condition	Suggested Parameters	Considerations
RDS Ground Glass, Air Broncho grams; consider HFV.	A/C Mode RR 30-50 PIP 24-28 VT: 4-6 ml/kg PEEP 6-8 IT 0.3-0.35	SpO2 response to appropriate PEEP levels reasonably quick. May need PIPs>28 to get reasonable chest rise and tidal volume Permissive Hypercarbia: PaCO2 45-60 mmHg
PIE Diffuse array of hyper lucent bubbles on CXR. Consider low MAP HFV	AC Mode RR 40 PIP <24 VT 4-5 ml/kg PEEP 5-6 IT 0.3	If unilateral over inflation, place infant with affected side down. Avoid gas trapping (see graphics) by reducing rate as needed
ELBW (w/o IRDS) CXR may appear clear.	AC Mode RR 40-60 PIP 16-22 VT 5-6 ml/kg PEEP 5 IT 0.25-0.3	Do Not Over Ventilate (low PaCO2) Permissive Hypercarbia: PaCO2 45-60 mmHg
SEPSIS Clear or Patchy Infiltrates	AC Mode RR 20-40 PIP 20-28 VT 5-6 ml/kg PEEP 4-5 IT 0.3-0.35	Avoid high MAP witch may restrict Pulmonary Perfusion
CDH Permissive Hypercarbia 1st 1-2 hours PH>7.15< 7.4 SpO2 > 70% 3-4 hours PH >7.17 SpO2 80% Hr 4 > 7.24, SpO2> 80%	AC Mode RR 50-60, PIP 16 VT 4-5 ml/kg PEEP 5 IT 0.25- 0.35 Max PIP =24—Start HFV: MAP =Conventional, or < 16; Hz 10 Consider iNO	Permissive Hypercarbia: PaCO2 45-60mmHg Monitor for PDA/R-L shunt Bowel loops up-NG Tachypnea, shallow respirations OK
Meconium Aspiration Granular, patchy infiltrates; Possible gas trapping with over distended diaphragms.	AC Mode RR 40 PIP 20-28 VT 6 ml//kg PEEP 6-8 IT 0.35-0.4	PPHN likely; start iNO early if rebound hypoxia present; consider HFV. Avoid gas trapping (see graphics) by reducing rate as needed
Hydrops/ Pulmonary Hypoplasia CXR: small lung fields, large abdomen	AC Mode RR 40-50 PIP 24-28 VT 4-5 ml/kg PEEP 5-6 IT 0.25-0.3	At Risk for pneumothorax, do not attempt to improve ventilation with excess PIP Consider HFV
HIE CXR often clear; infants with vigorous respiratory effort.	SIMV/PS/CPAP RR 10-30 PIP 16- 22 VTs 6-8cc/kg PEEP 5 IT 0.3-0.4 PS 8-10cmH2O to support Spont RR	Infants may be capable of supporting own ventilation but need airway control for transport—PS/CPAP. Use lower rates to avoid low PaCO2
CHD/CHF CXR may reveal lg heart, hazey lung fields,	AC Mode RR 40 PIP 24-30 VT 6-8cc/kg PEEP 5-10 IT 0.3- 0.4	iNO if questionable PHTN/ R/O PDA dependent
BPD CXR usually a mix of patchy infiltrates, large heart, over inflated lungs	AC Mode RR 20-40 PIP 24-30 VT 6-8 ml/kg PEEP 6-8 IT 0.4-0.6	Lower Rates preferred if evidence of trapping—flow loops, slow emptying on scalers. Avoid gas Trapping. Tidal volumes> 8 ml/kg may be needed for advanced disease and adequate chest rise
CCAM CXR reveals large blebs—adjacent lung fields often compressed/collapsed	AC Mode RR 20-30 PIP 18-24 VT 4-5 ml/kg PEEP 4-5 IT 0.3-0.35	If unilateral, position with affected side down

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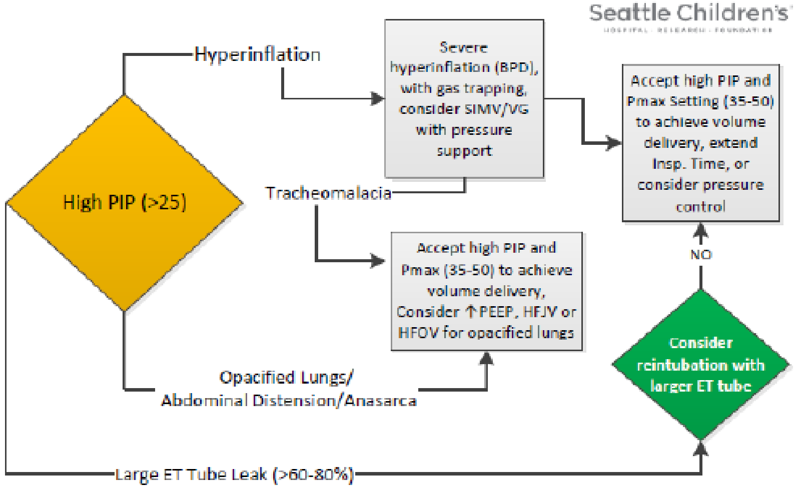
Adapted from Dargaville & Keszler, 2013

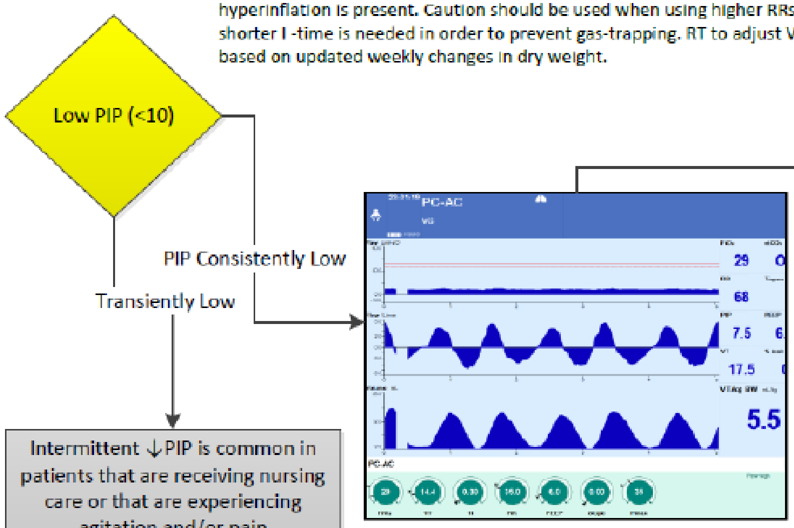
Seattle Children's NICU Volume Targeted Ventilation Management Guidelines

All newborns admitted to the SCH NICU requiring conventional mechanical ventilation will be supported initially using assist-control volume-guarantee (ACVG) mode

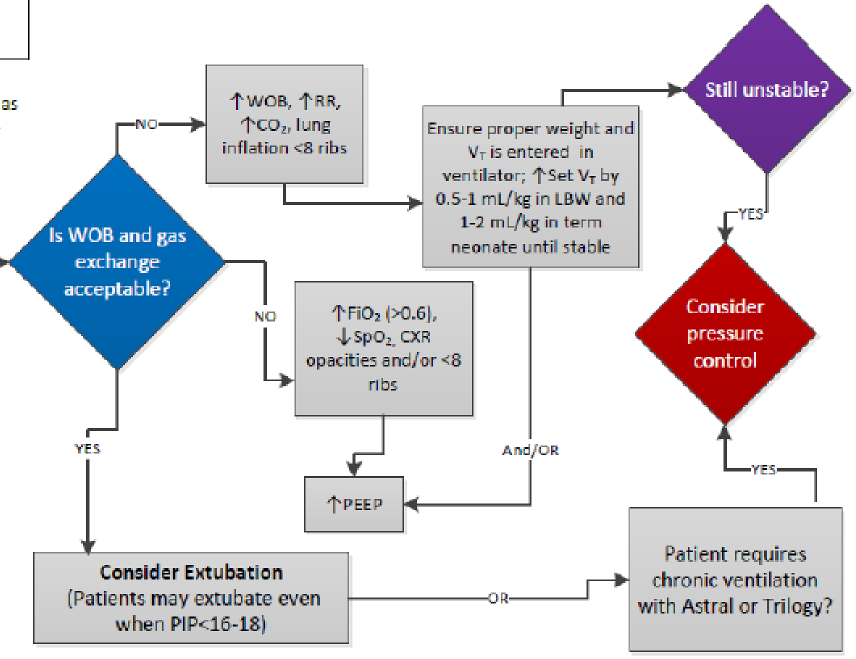
Weight - Age	Tidal volume (mL/kg)	PEEP (cmH_2O)	Rate	I Time (s)
At Birth				
< 1.0 kg	4-6	5-7	40-60	0.25-0.3
1.0-1.5 kg	5-6	5-8	40	0.3-0.35
> 1.5 kg	6-7	5-8	40	0.3-0.4
CDH*	4-5	5-6	40-60	0.3–0.4
At > 2 wks on ventilator†	Consider increase V_T by 0.5 – 1.5 mL/kg	5-8	20-40	0.35-0.45
BPD – moderate (> 4 wks)†	6-8	6-10	20-40	0.35 -0.45
BPD – severe (> 4 wks)†	7-10	7-10	20-30	0.4 -0.6

*Refer to CDH guideline;†SIMV/VG should be considered when hyperinflation is present. Caution should be used when using higher RRs, as shorter I -time is needed in order to prevent gas-trapping. RT to adjust V_T based on updated weekly changes in dry weight.





Patient experiencing low PIP (upper scalar) due to patient V_T>set V_T



Developed by Rob DiBlasi, Kendra Smith, Craig Jackson, and Bob DiGeronimo

DiBlasi, Robert, Kendra Smith, Craig Jackson, and Bob DiGeronimo. *Seattle Children's NICU Volume-Targeted Ventilation Management Guideline*. Seattle Children's Hospital.

Protective Ventilation Strategies for the ELBW Premature Neonate

- **GOAL: Maintain <u>adequate</u> gas exchange while minimizing ventilator-associated lung injury**
  - WEAN AGGRESIVELY to maintain oxygenation and ventilation targets
  - Prevent lung injury!

- **STRATEGIES:**
  - On Conventional Mechanical Ventilation:
    - Minimal ventilation with permissive hypercapnia
      - Low tidal volumes: 4-6 mL/kg for premature infants
      - Target PaCO2 45-55
        - Neurologic protection
      - pH>7.25 *wean faster, extubate sooner*
    - Goal SpO2: 91-95%
  - Non-invasive when possible:
    - CPAP, NIPPV
  - High Frequency Jet Ventilation (HFJV) or High Frequency Oscillatory Ventilation (HFOV)

Target Blood Gas:
pH: 7.25-7.35
$PaCO_2$: 45-55
PaO_2: 50-70
HCO_3: 19-22

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NICU
Patient Scenario

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Patient Arrives In The NICU:

- **Gestational Age:** 25 weeks
- **Birth Weight:** 500 grams
- **Sex:** Female
- **Delivery:** Vaginal delivery following preterm labor
- **Apgar Scores:** 3 at 1 minute, 5 at 5 minutes
- **Antenatal Steroids:** Partial course
- **Surf x 1**

Airway:

- Endotracheal tube size 2.5 mm
- Secured at 5.5cm at the lip

Breathing:

- Diminished breath sounds bilaterally
- mild retractions
- Poor chest expansion

Temperature:

- 36.2°C

Baseline Vital Signs

- **Heart Rate:** 168 bpm
- **RR:** 46
- **SpO_2:** 90% on FiO_2 0.30
- **Blood Pressure:** 38/20 (MAP 26)

Initial Vent Settings
A/C + Volume Guarantee (AC/VG)

Vent Settings:

- **Target Tidal Volume:** 2.5 mL *(5 mL/kg - 4-6 mL/kg)*
- **Ventilator Rate:** 45 *(40-60)*
- **PEEP:** +6 *(5-7 cmH_2O)*
- **FiO_2:** 0.40
- **Inspiratory Time:** 0.25s *(0.25-0.30s)*
- **Maximum PIP Limit:** 26

Monitored Values:

- **Tidal Volume:** 5.5 mL
- **Respiratory Rate:** 60
- **PEEP:** +6
- **FiO_2:** 0.40
- **Inspiratory Time:** 0.25s
- **PIP:** 22
- **SpO2:** 91%

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Follow Up ABG:

pH: 7.21
$PaCO_2$: 62 mmHg
PaO_2: 54 mmHg
HCO_3: 24 mEq/L

What vent changes would you like to make?

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A/C + Volume Guarantee (AC/VG)

Vent Settings:

- **Target Tidal Volume:** 2.75 mL *(5.5 mL/kg)*
- **Ventilator Rate:** 45
- **PEEP:** +6
- **FiO_2:** 0.40
- **Inspiratory Time:** 0.25s
- **Maximum PIP Limit:** 28

Monitored Values:

- **Tidal Volume:** 2.8 mL
- **Respiratory Rate:** 55
- **PEEP:** +6
- **FiO_2:** 0.40
- **Inspiratory Time:** 0.25s
- **PIP:** 24
- **SpO2:** 91%

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6 HOURS LATER

A/C + Volume Guarantee (AC/VG)

Vent Settings:

- **Target Tidal Volume:** 2.5 mL *(5.5 mL/kg)*
- **Ventilator Rate:** 45
- **PEEP:** +6
- **FiO_2:** 0.60
- **Inspiratory Time:** 0.25s
- **Maximum PIP Limit:** 28

Monitored Values:

- **Tidal Volume:** 2.6 mL
- **Respiratory Rate:** 55
- **PEEP:** +6
- **FiO_2:** 0.60
- **Inspiratory Time:** 0.25s
- **PIP:** 27
- **SpO2:** 89%

What does an increasing PIP and increased FiO2 indicate about your patient?

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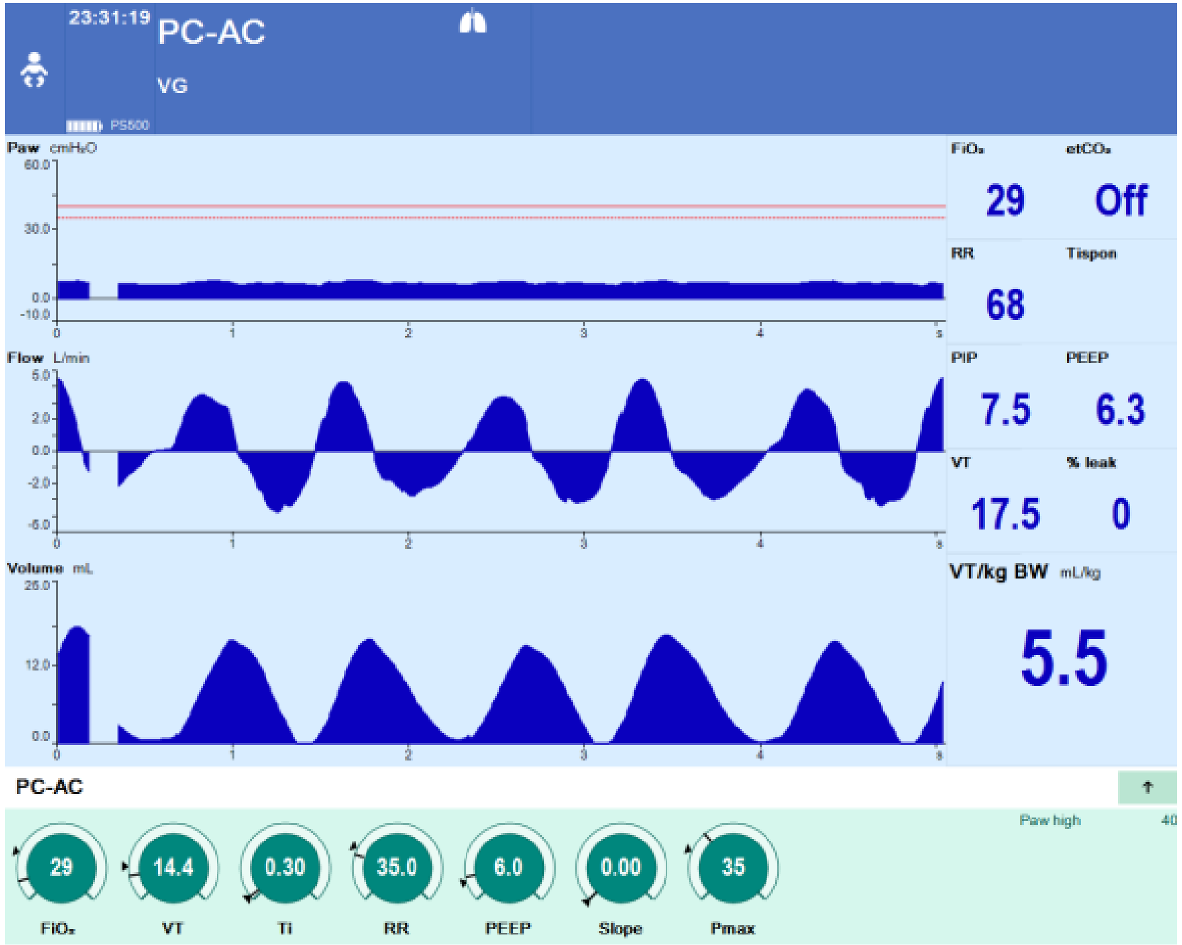
6 HOURS LATER
A/C + Volume Guarantee (AC/VG)

- Low PIP alarm for consistently reading PIPs **8-9**
- Patient vitals:
  - RR: 85
  - SpO2: 87%
  - Moderate-severe retractions
  - Measured Vt: 8 mL/kg

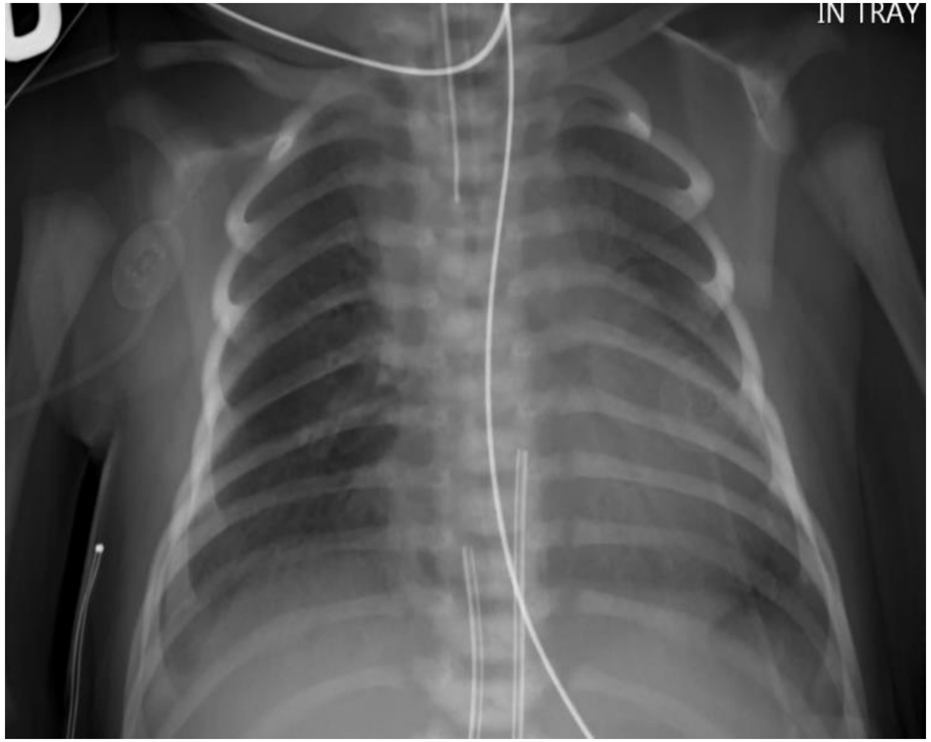
What is happening with your patient?

Inappropriate Support During Volume Guarantee

Pt wt: 3.2 kg



4.5 mL/kg



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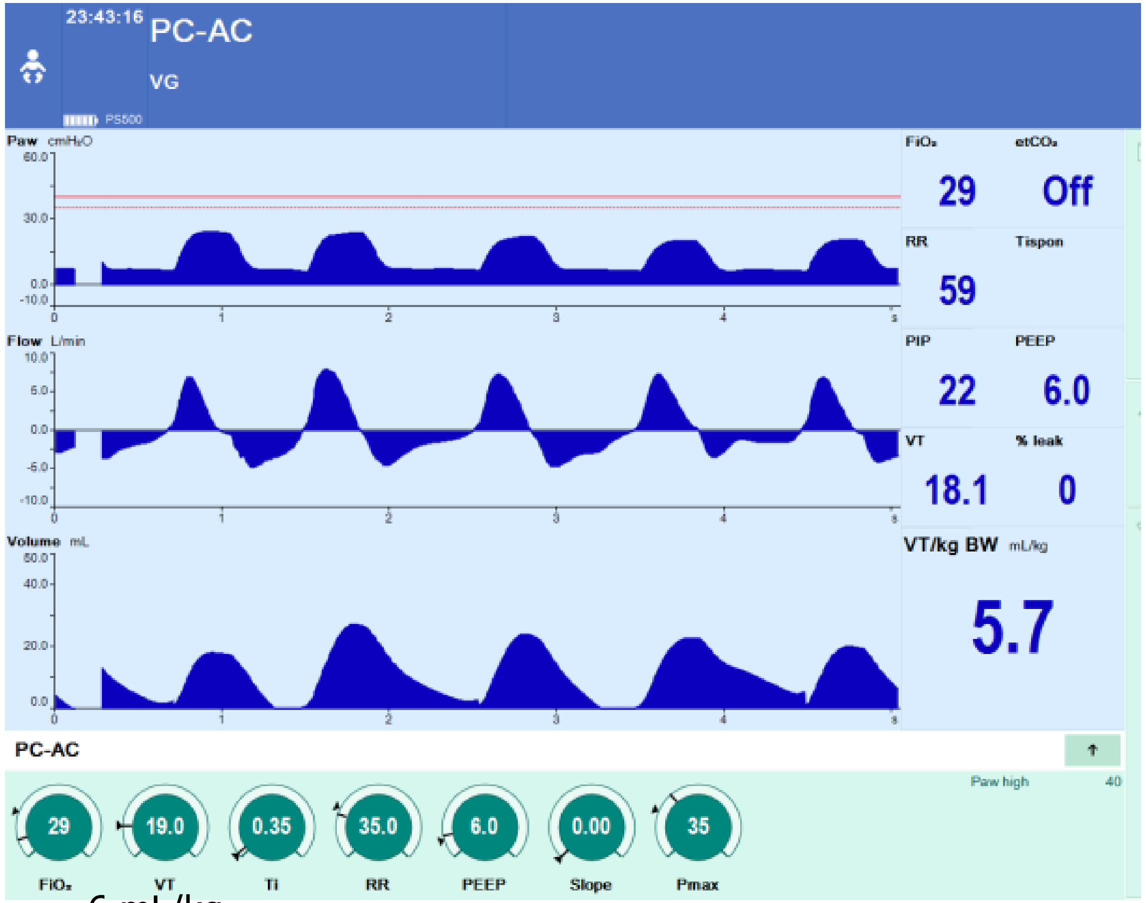
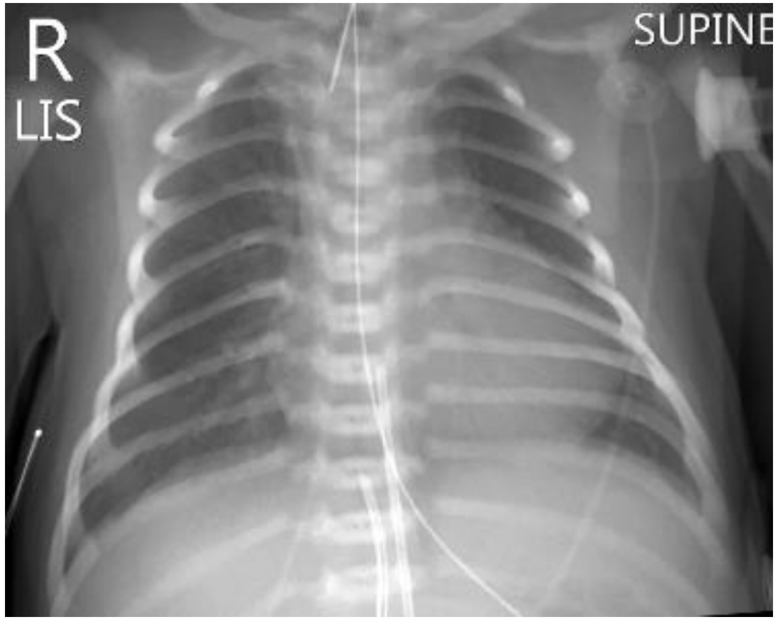
ABG: 7.21/55/65/20

Appropriate Support During Volume Guarantee

Pt wt: 3.2 kg



6 mL/kg



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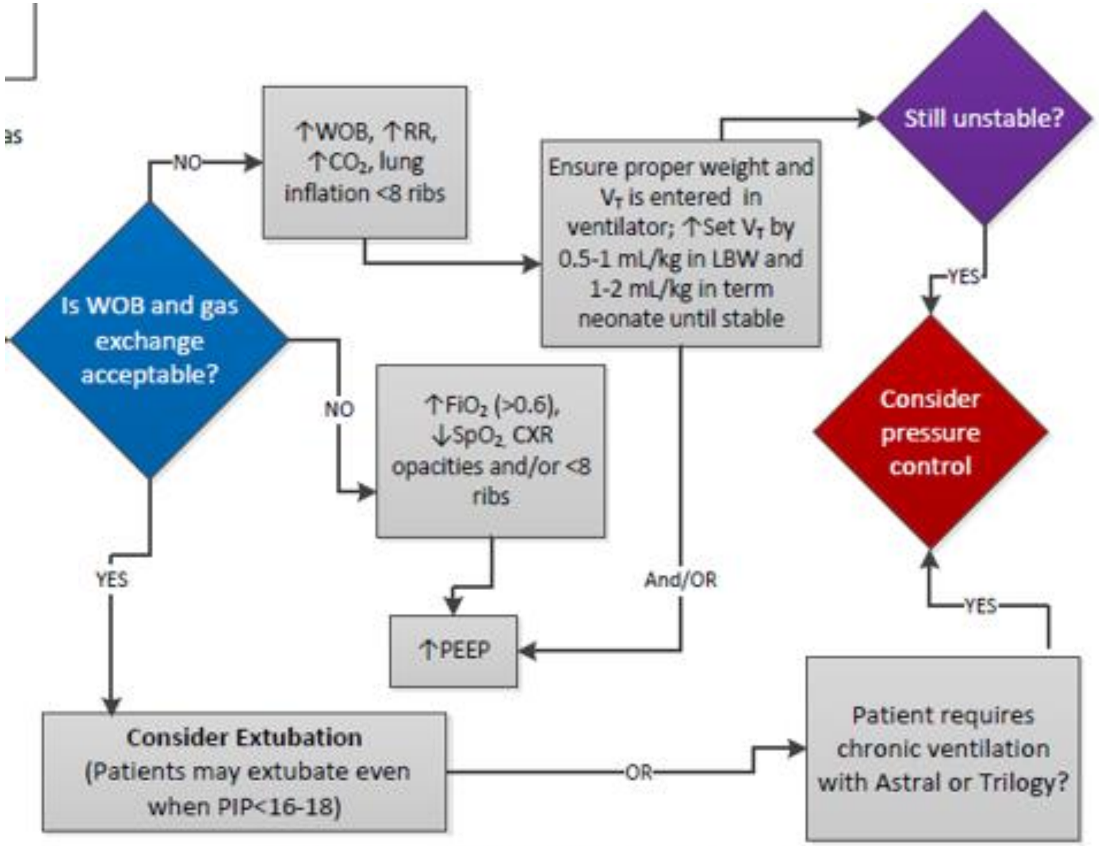
Is your PIP consistently <10?

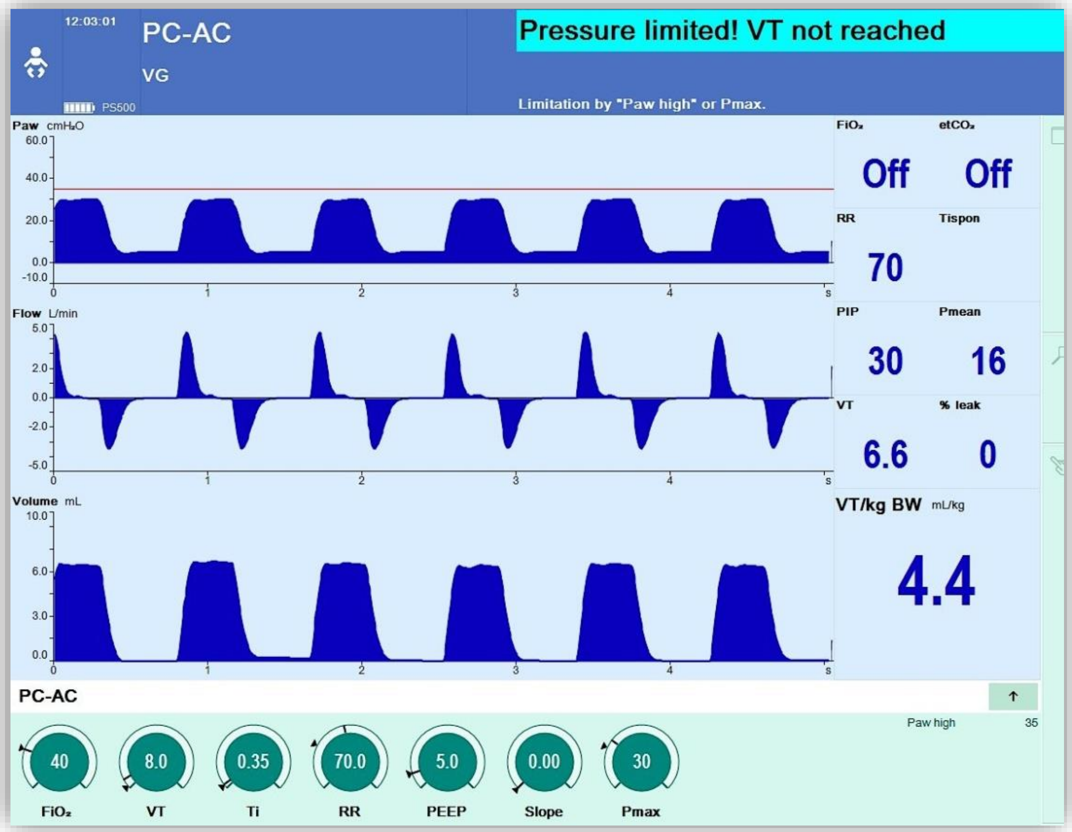
- Is flow sensor working appropriately?
- How does your patient look?
  - WOB
  - ETT position
  - TCM/Co2
  - SpO2
  - CXR – lung expansion
- Are Vt consistently above targeted volume?
  - Has the pt weight been updated?
    - If DCW is considerably lower, don't change it
    - If abnormally high (non-linear, discuss it with team to look at I + Os, presence on anasarca on CXR
  - Increase Vt appropriately
  - Goal: low WOB with sufficient pressures to prevent lung collapse on VG without having to go to PC



Developed by Rob DiBlasi, Kendra Smith, Craig Jackson, and Bob DiGeronimo

6 HOURS LATER
A/C + Volume Guarantee (AC/VG)

- High PIP Alarm going off
- Low tidal volume alarm going off
- Delivered tidal volume below target
- Rising $PaCO_2$



What are possible causes of consistently high PIPs?

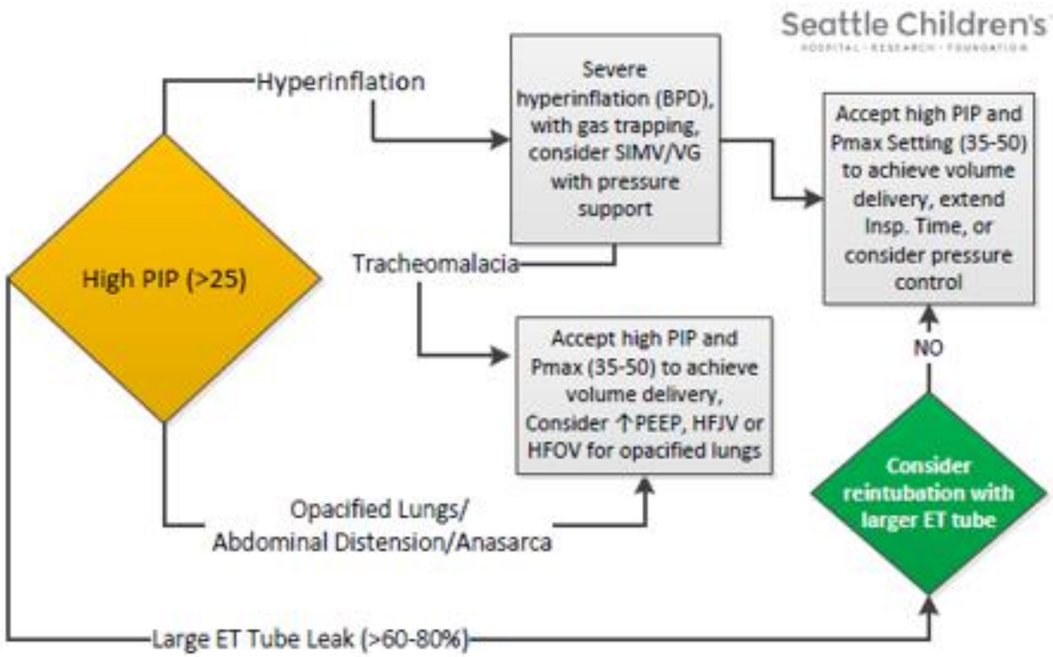
PIP >25, Low Tidal Volumes

- Is flow sensor and ventilator working appropriately?
  - Is filter saturated?

- What does patient look like?
  - Secretions?
  - Obstruction in ETT?
  - Pneumothorax?
  - Verify ETT placement
  - CXR: lungs / Abdominal assessment

- Is ETT appropriate size for GA?
  - Is leak reading 60%-80%?
  - Is leak seen on waveforms/vent loops?
  - Is apnea alarm going off?
    - Reintubation with larger ETT

- Is patient air-trapping?
  - Evaluation of TC
  - What is I-time / E-time?
  - Is exp flow reaching 0?
    - May consider switch to SIMV-PC



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2 Weeks Later
A/C + Volume Guarantee (AC/VG)
(weight : 1 kg)

Vent Settings:

- **Target Tidal Volume:** 6 mL *(6 mL/kg)*
- **Ventilator Rate:** 30
- **PEEP:** +6
- **FiO_2:** 0.25
- **Inspiratory Time:** 0.30s
- **Maximum PIP Limit:** 26

Monitored Values:

- **Tidal Volume:** 6.1 mL
- **Respiratory Rate:** 35
- **PEEP:** +6
- **FiO_2:** 0.25
- **Inspiratory Time:** 0.30s
- **PIP:** 16
- **SpO2:** 95%

ABG: 7.36/46/68/20
What changes would you make?

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Extubation Readiness

Stable ABG: pH > 7.25, $PaCO_2$ < 60 mmHg, PaO_2 > 50 mmHg on $FiO_2 \leq 0.3$–0.4
Ventilator Settings: PIP ≤ 14–18 cmH_2O, rate ≤ 40 bpm, MAP ≤ 8–10 cmH_2O
Clinical Stability: Minimal apnea/bradycardia, manageable secretions, good spontaneous effort
Caffeine: Ensure therapeutic levels before extubation
Avoid SBTs: Spontaneous breathing trials are not routinely recommended in neonates
NIPPV>CPAP: reducing failure in very preterm infants

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How Do I Start To Create Mechanical Ventilator Guidelines?

Engage stakeholders and champions (RCP, MD, RN) early and often

Present literature review

Conduct benchmarking with other top Children's Hospitals / NICUs

Draft your protocol

Review/revise with stakeholders – get their feedback and buy-in!

Educate and Implement

Must have continuous monitoring of compliance and outcomes!

Review, Re-educate, Review, Re-educate!


Aligning for Excellence
NICU VENTILATION GUIDELINES
Evidence-Based. Patient-Centered. Team-Aligned.
LUNG PROTECTION
• Target appropriate volumes
• Avoid overdistension
• Use the lowest effective settings
OPTIMAL OXYGENATION
• Target SpO_2 90–95%
• Avoid hyperoxia
• Wean FiO_2 first
SUPPORT THE PATIENT
• Support, don't overventilate
• Consider the whole patient
CONSISTENT PRACTICE
• Follow guideline recommendations
• Communicate and align as a team
Right support. Right baby. Right time.
Our goal is simple... the best outcomes for our tiniest patients.
One Team One Plan One Goal
CHOC
NICU
Small Patients Big Impact
Our Priorities
Safety
Evidence
Consistency
Communication
Compassion
Stronger together for our tiniest patients
NICU TEAM

Key Takeaways

Mechanical ventilation is a risk factor for both acute and chronic lung injury in ELBW neonates

VILI is a significant risk factor for developing BPD

If mechanical ventilation is necessary, utilize lung protective strategy:

- Volume-targeted ventilation (VTV) to minimize end-inspiratory alveolar overdistention
- Sufficient PEEP to optimize FRC
- For infants requiring invasive ventilation, volume-targeted ventilation should be preferred to minimize lung injury
- A/C associated with lower WOB and more consistent Vt / minute ventilation

Develop disease-specific ventilation guidelines with protocolized, structured weaning approach

THIS IS YOUR MOMENT TO SHINE AS AN RT LEADER!

Emilee.Lamorena@Choc.Org

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