VENTILATION PARAMETERS

Indications for IMV

- **Clinical parameters**
- ↑ WOB
- Respiratory fatigue
- Shock
- Apneas on CPAP
- CNS depression: Decreased activity and movement
- Anesthesia

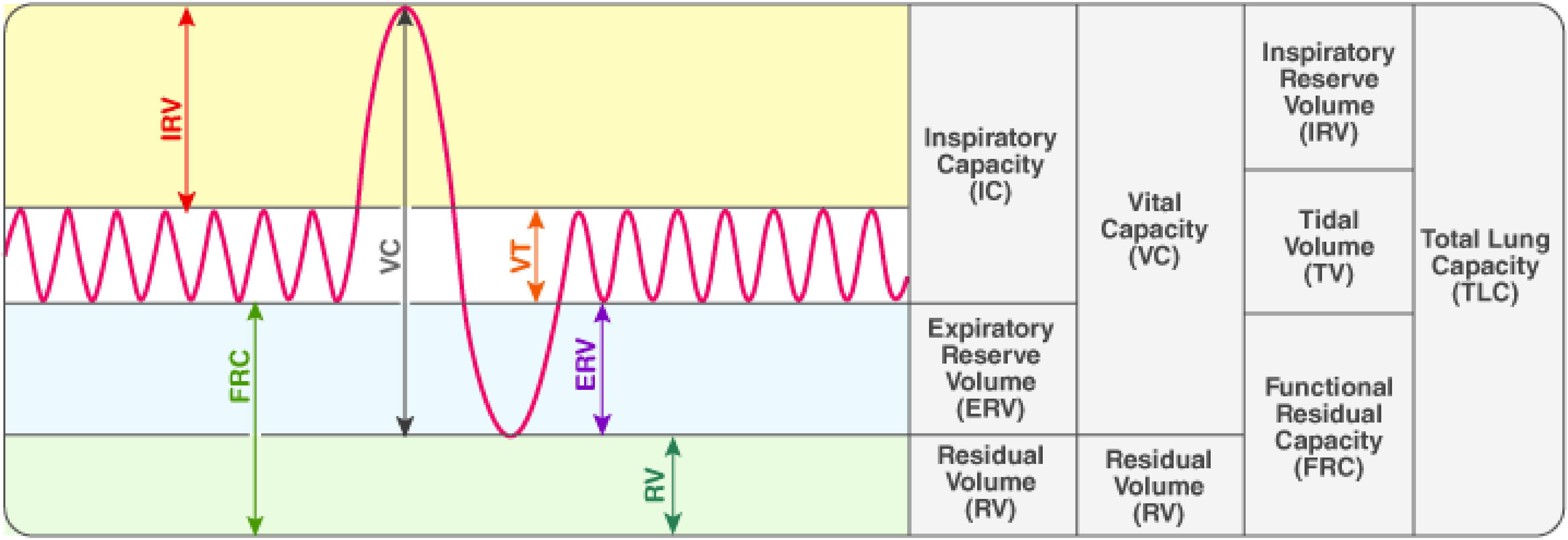
Laboratory Criteria

- Hypoxia at CPAP 8
  - $PaO_2 < 50$
- Respiratory acidosis
  - $pH < 7.25$, $pCO_2 > 60$

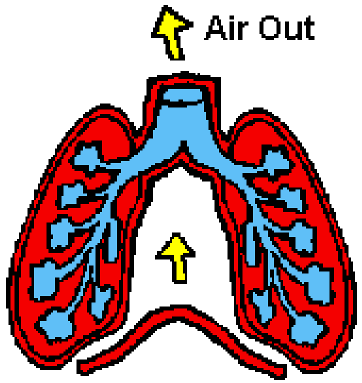
LEARNING OBJECTIVE

1. Ventilation.
2. Oxygenation.
3. Basic mechanics of neonatal mechanical ventilation.

LUNG'S VOLUMES AND CAPACITIES



VENTILATION v/s OXYGENATION



VENTILATION

- Movement of gas in and out.
- Pertains to lung alone.
- Pco2 levels tells about the adequacy of ventilation(not po2 levels).

CARBON DIOXIDE REMOVAL

- Determined by MINUTE VENTILATION

$$MV = Vt \times RR$$

- Vt can be increased by INCREASE IN △P
  - PIP-PEEP

- MINUTE VENTILATION

  PRACTICAL GOLD STANDARD PARAMETER

  =Vt x RR

  =Alveolar ventilation + Dead space ventilation

  Normal range=200-300ml/kg/min

- ALVEOLAR VENTILATION

  Ideal Gold Standard parameter for ventilation

  In practice , we use MV as a surrogate marker

IMPORTANCE OF DEAD SPACE

- Dead space is indirectly dependent on gestational age and weight.
- Therefore, it is more in extremely low birth weight babies than in more mature infants.

EXAMPLE:

• 3kg baby.	1KG baby
• Vt=12ml	Vt=4ml
• Dead space=6ml.	Dead space=3ml
• Alveolar ventilation=6mlxRR.	Alveolar ventilation=1mlxRR

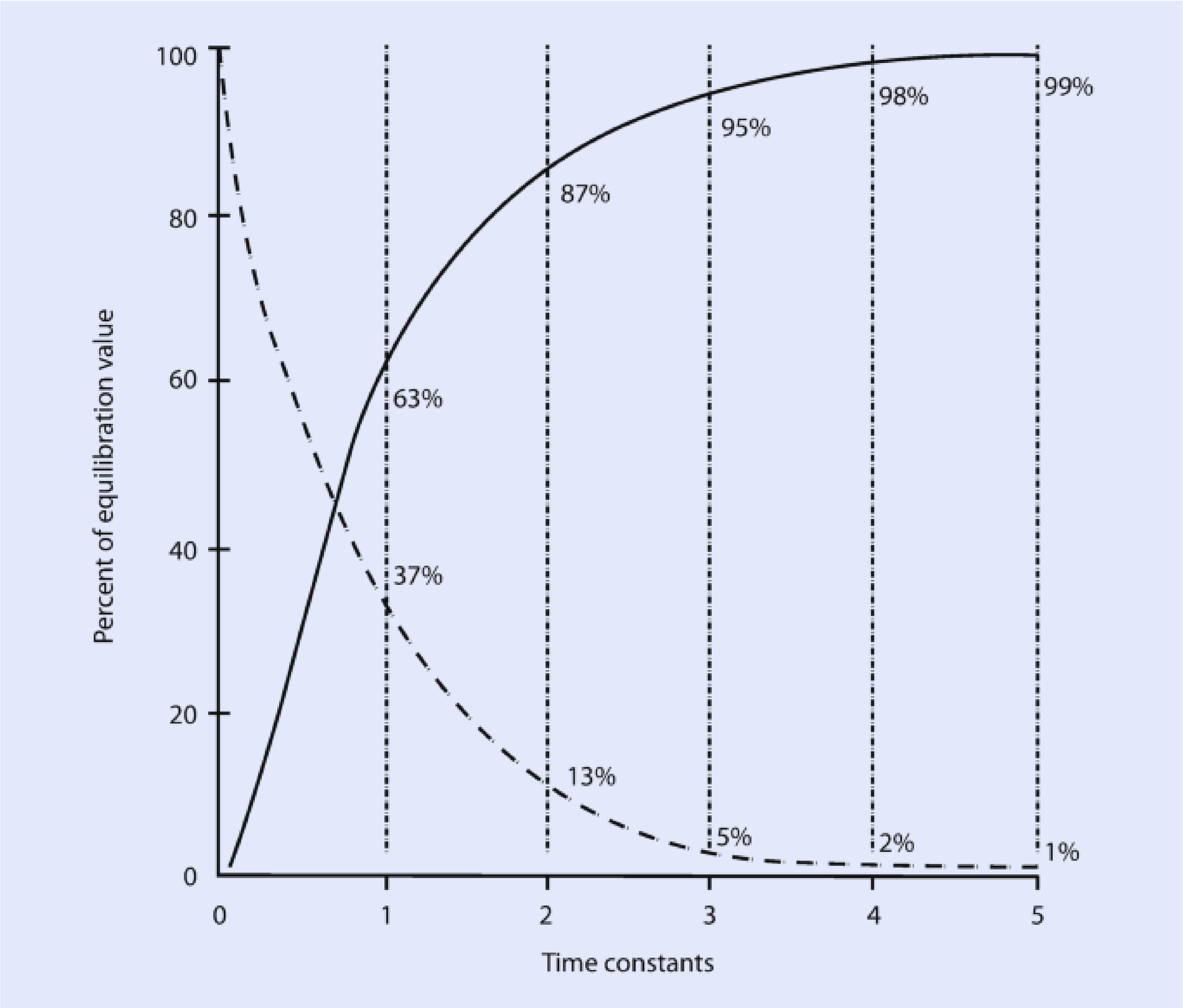
- Dead space is proportionally more significant in smaller Babies.
- Smaller babies need proportionally larger tidal volume while ventilating.

- TV Target:
  - Preterm-6ml/kg
  - Term-4ml/kg

TIME CONSTANT

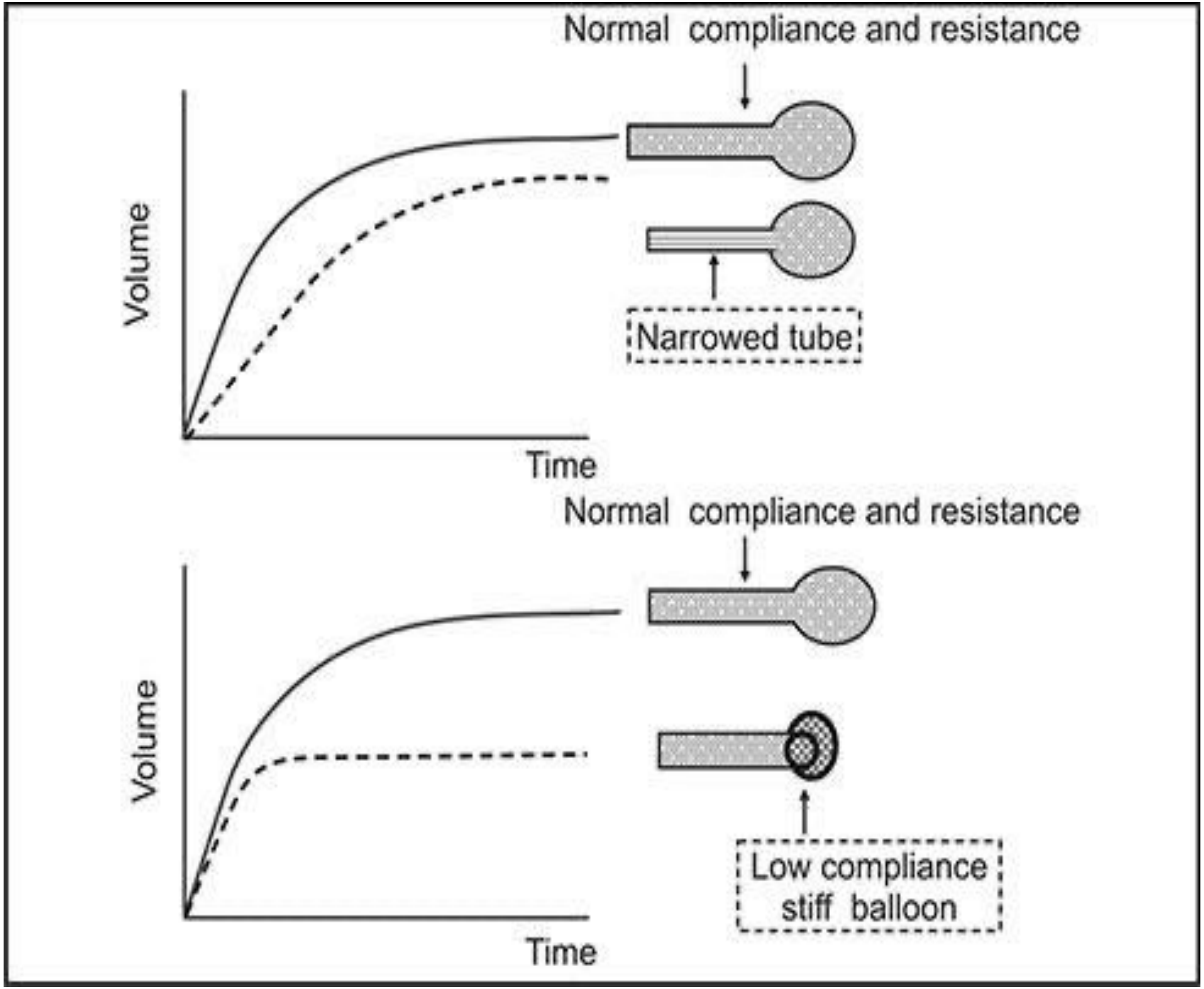
- Time taken for airway pressure and volume changes to equilibrate throughout lungs
- Compliant X Resistance.
- 1 Tc= Is to exhale/inhale 63% tidal volume.

Why do we need to know this time?



Percent of equilibration value
100
80
60
40
20
0
0
1
2
3
4
5
Time constants
63%
87%
95%
98%
99%
37%
13%
5%
2%
1%

- 3-5 Tc needed for adequate Ti / Te
- Short Ti - decreased ventilation
- Short Te- air trapping

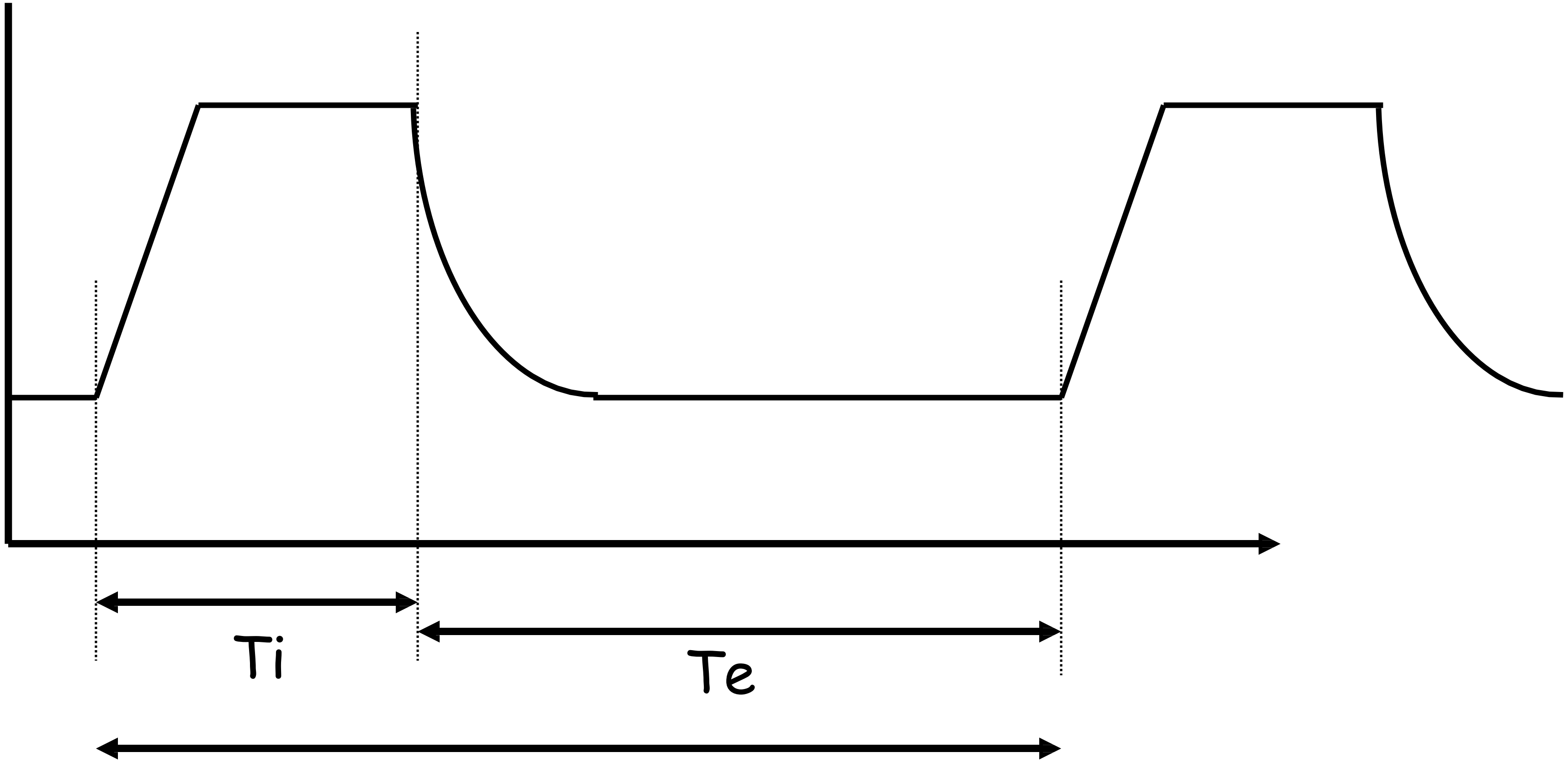

Normal compliance and resistance
Volume
Time
Narrowed tube
Normal compliance and resistance
Volume
Time
Low compliance
stiff balloon

Rate

- Rate is decided by TC
- Less time constant rapid rate to be set (RDS)
- Increase time constant, Less RR to set (MAS)
- Normal rate for neonatal lung disease 20-60
- Adequacy of Ti/Te to be decided by flow or pressure time graph

Assisted ventilation of the neonate, Sixth edition, 2017

RR, Ti & Te



1 resp cycle= Ti + Te

RR = 60 sec/duration of 1 resp cycle = 60/Ti + Te

How to set Ti

- Choices are between 0.3 to 0.5
- If insp T.C. is expected to be:
  - normal: 0.40-0.45 sec
  - short: 0.30 to 0.40
  - long: 0.5

Normal (1:2 to 1:3)

How to set RR

- Choices are between 20 to 60
- Considerations are:
  - work of breathing?
  - is there asynchrony: need for overdrive?

WOB	normal	↑	↑↑
Asynchrony	minimal	+	+ +
Pressure need	minimal	+	+ +
RR	~ 20	~ 40-50	~ 50-60

Examples

- If Ti = 0.3 sec & Te = 0.7 sec

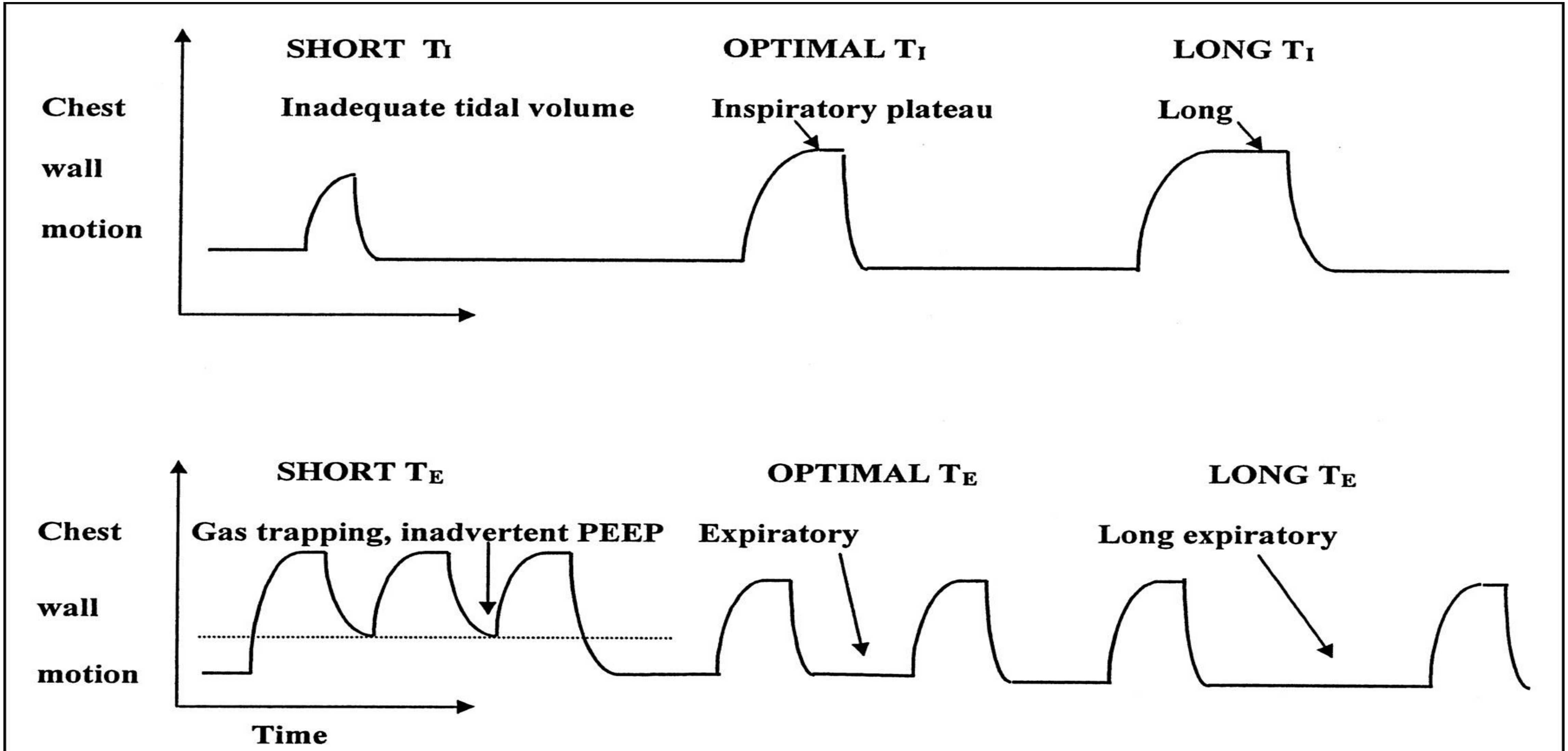
  RR = 60/(0.3 + 0.7) = 60/1 = 60/min
- If RR = 80/min & Ti = 0.35

  1 resp cycle= 60/80 = 0.75 sec

  Te= 0.75 - 0.35 = 0.4 sec
- If RR = 40 & I:E ratio = 1:2 1 resp cycle= 60/40= 1.5 sec Ti= 0.5 sec, Te= 1 sec

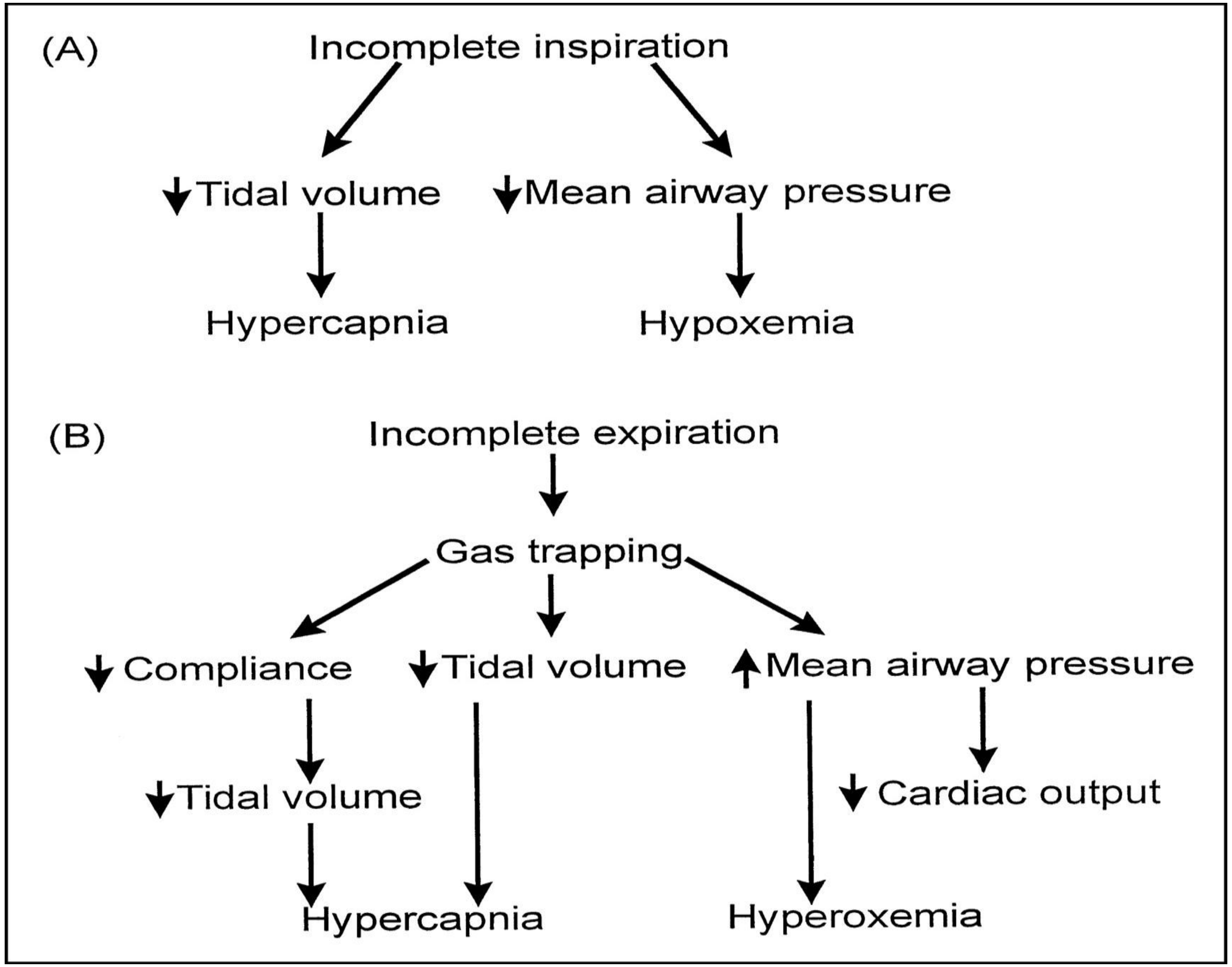
If you know any 2, the 3rd can be calculated !

Effect



SHORT TI
OPTIMAL TI
LONG TI
Chest wall motion
Inadequate tidal volume
Inspiratory plateau
Long
SHORT TE
OPTIMAL TE
LONG TE
Chest wall motion
Gas trapping, inadvertent PEEP
Expiratory
Long expiratory
Time

Effects of incomplete inspiration (A) or incomplete expiration (B) on gas exchange.

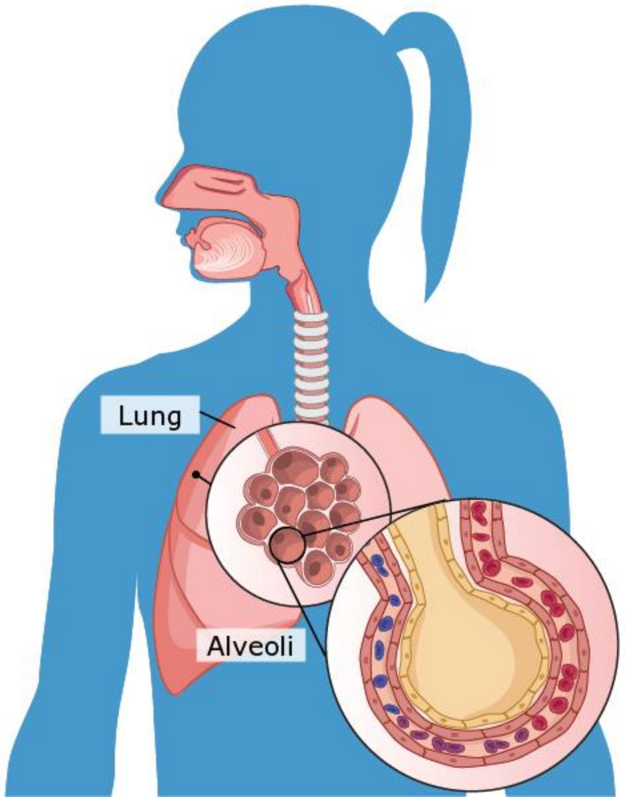


Waldemar A. Carlo, and Namasivayam Ambalavanan Pediatrics in Review 1999;20:e117-e126

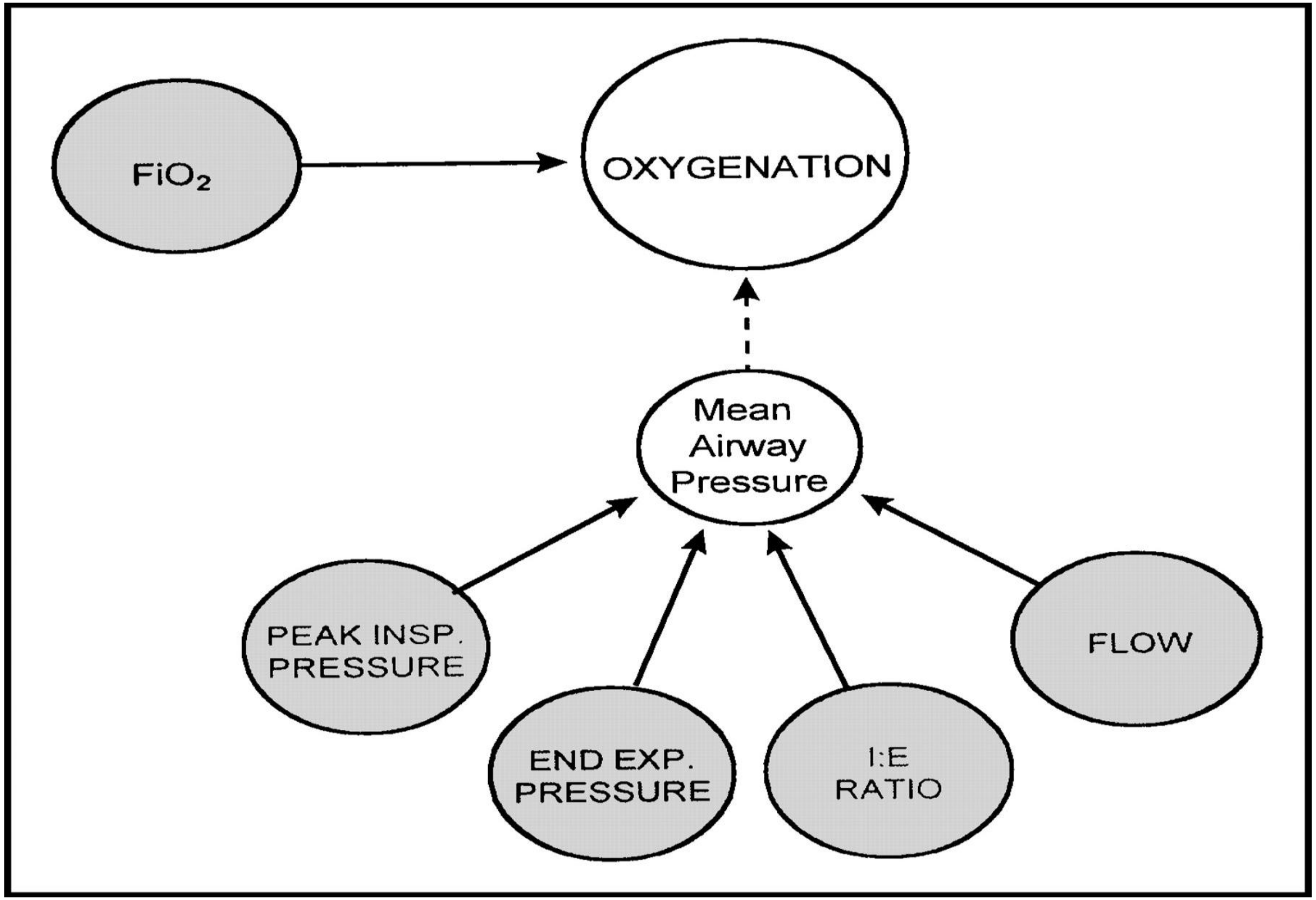
Pediatrics in Review®
AN OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

OXYGENATION(Po2 levels)

- Increase the oxygen uptake through lungs.
- Other parameters also contribute:
  - Hemodynamics-cardiac, blood vessels.
  - Hb, PCV.
  - Comorbidities-sepsis,increase demand ,etc.



Determinants of oxygenation during pressure-limited, time-cycled ventilation.



Waldemar A. Carlo, and Namasivayam Ambalavanan Pediatrics in Review 1999;20:e117-e126

Pediatrics in Review®
AN OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

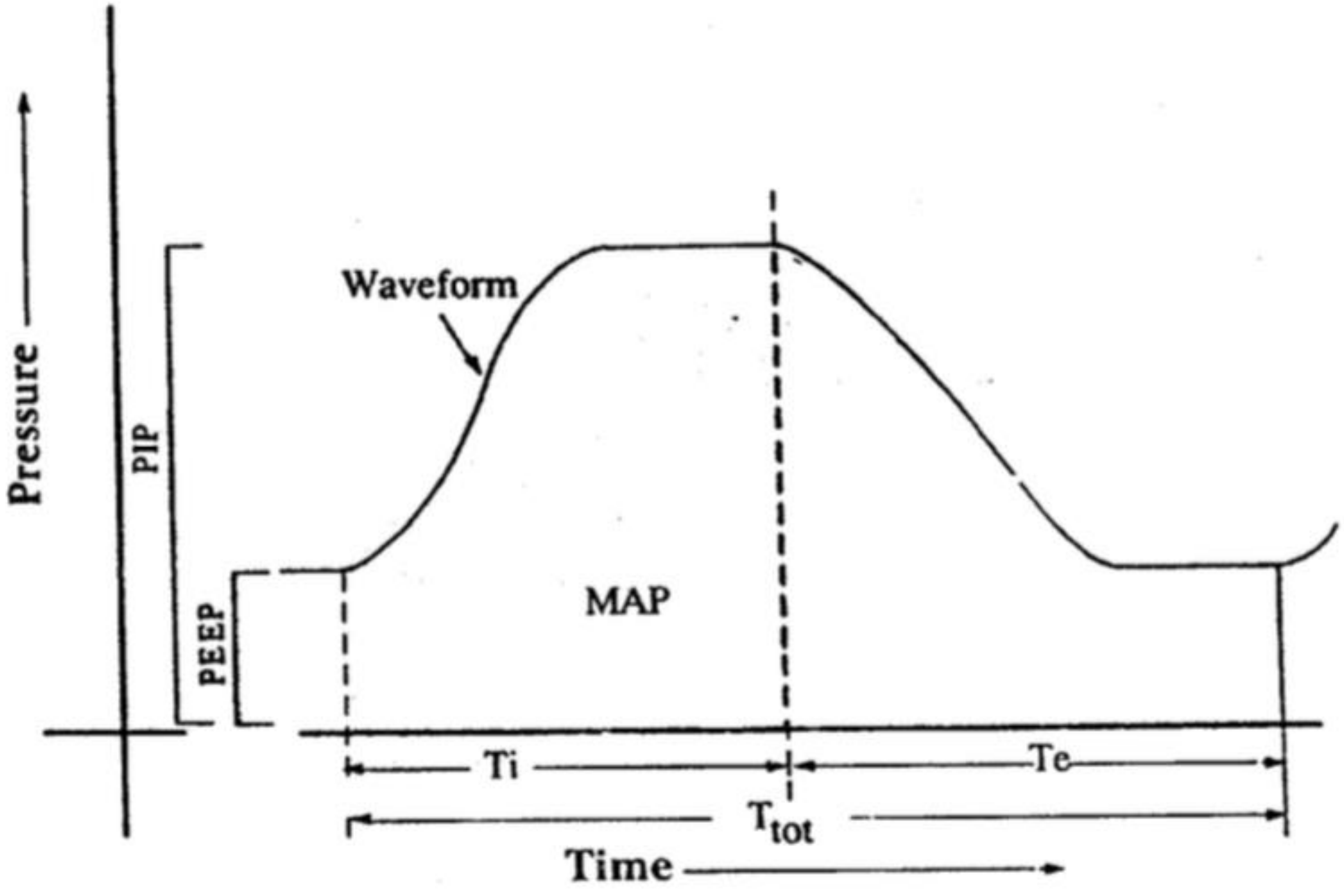
Mean airway pressure

- Mean pressure applied during positive-pressure mechanical ventilation.
- Determines oxygenation

Mean Airway Pressure $(\overline{P}aw)$

$$\overline{P}aw = \frac{(T_I \times PIP) + (T_E \times PEEP)}{Ttot}$$

Respiratory cycle on PPV



Mean airway pressure

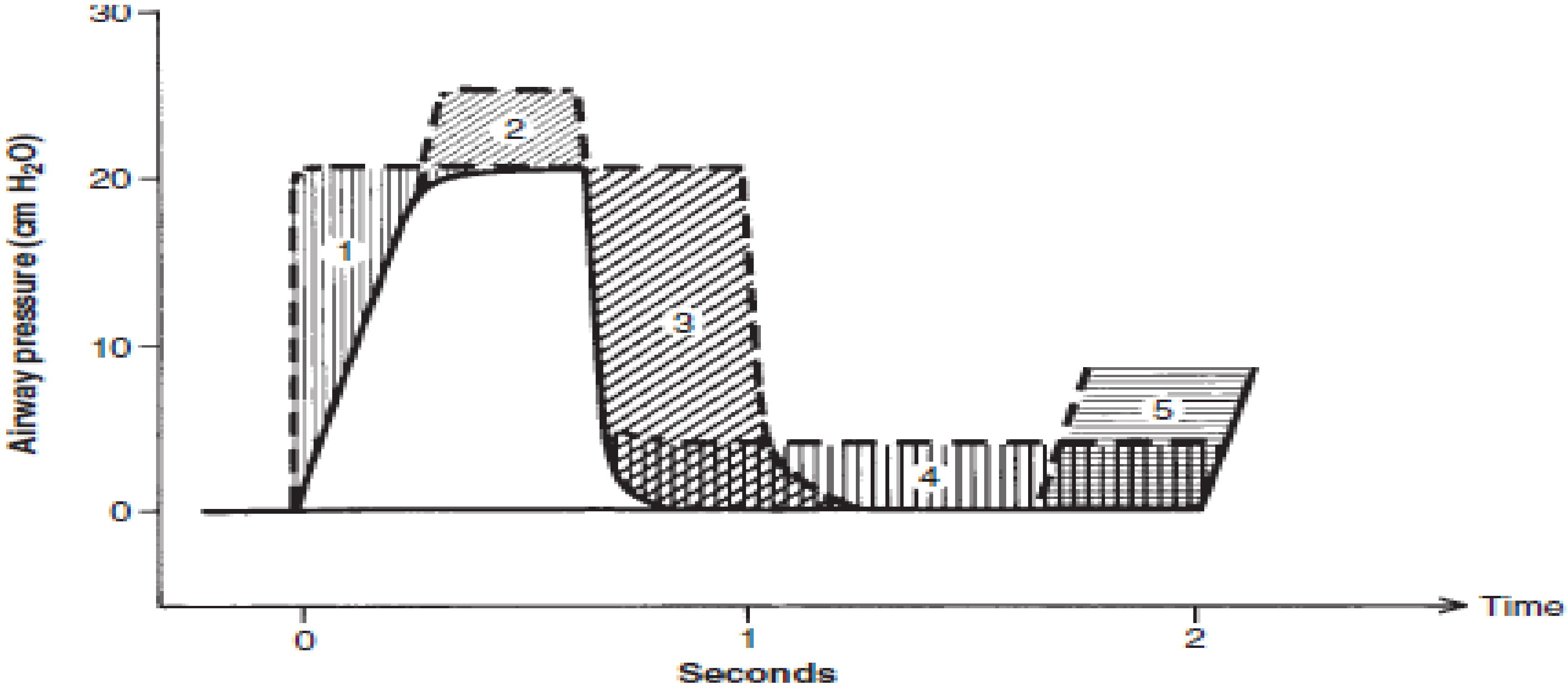


FIG 2-15 Five different ways to increase mean airway pressure: (1) increase inspiratory flow rate, producing a square-wave inspiratory pattern; (2) increase peak inspiratory pressure; (3) reverse the inspiratory-to-expiratory ratio or prolong the inspiratory time (I-time) without changing the rate; (4) increase positive end-expiratory pressure; and (5) increase ventilatory rate by reducing expiratory time without changing the I-time. (Modified from Reynolds EOR. Pressure waveform and ventilator settings for mechanical ventilation in severe hyaline membrane disease. *Int Anesthesiol Clin*. 1974;12:259.)

Assisted ventilation of the neonate, Sixth edition, 2017

Mean airway pressure

- When need to increase oxygenation, increase MAP/FiO_2.

- When lung volume are small (RDS, pneumonia) prefer to increase MAP

- When lung volume large (MAS, PIE) or air leak prefer to increase FiO_2

Peak inspiratory pressure

- Peak pressure during the inspiratory phase of the respiratory cycle.

- PIP increases tidal volume and MAP (improves ventilation and oxygenation)

- Predisposes to barotrauma (22/24 in PT/term)

- Impairs venous return

How to set PIP

- Lowest PIP which adequately ventilates the patient
- Choices are between 12 to 20
- If compliance is normal, set 12
- If compliance is less, set appropropiate PEEP & observe chest rise

  - mildly stiff: 12-14 cms
  - Moderately stiff: 16-18
  - severely stiff: 20+

PEEP

- Positive pressure in the airway at the end of expiration .
- Maintains FRC and reduces V/Q mismatch
- Ideal PEEP : minimal intercostal and subcostal retraction and adequate lung expansion in chest X ray.
- High PEEP: air trapping, pneumothorax, reduced CO

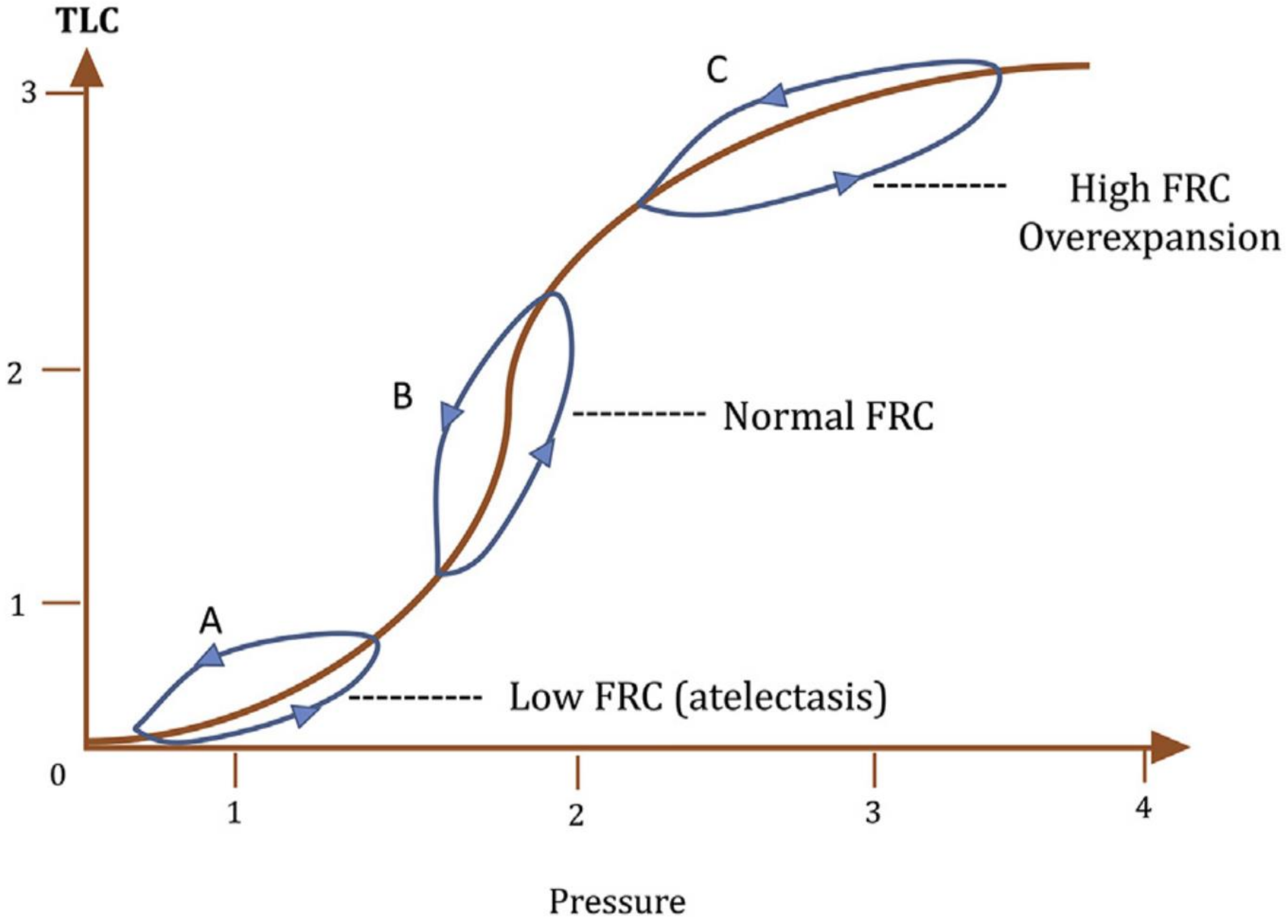
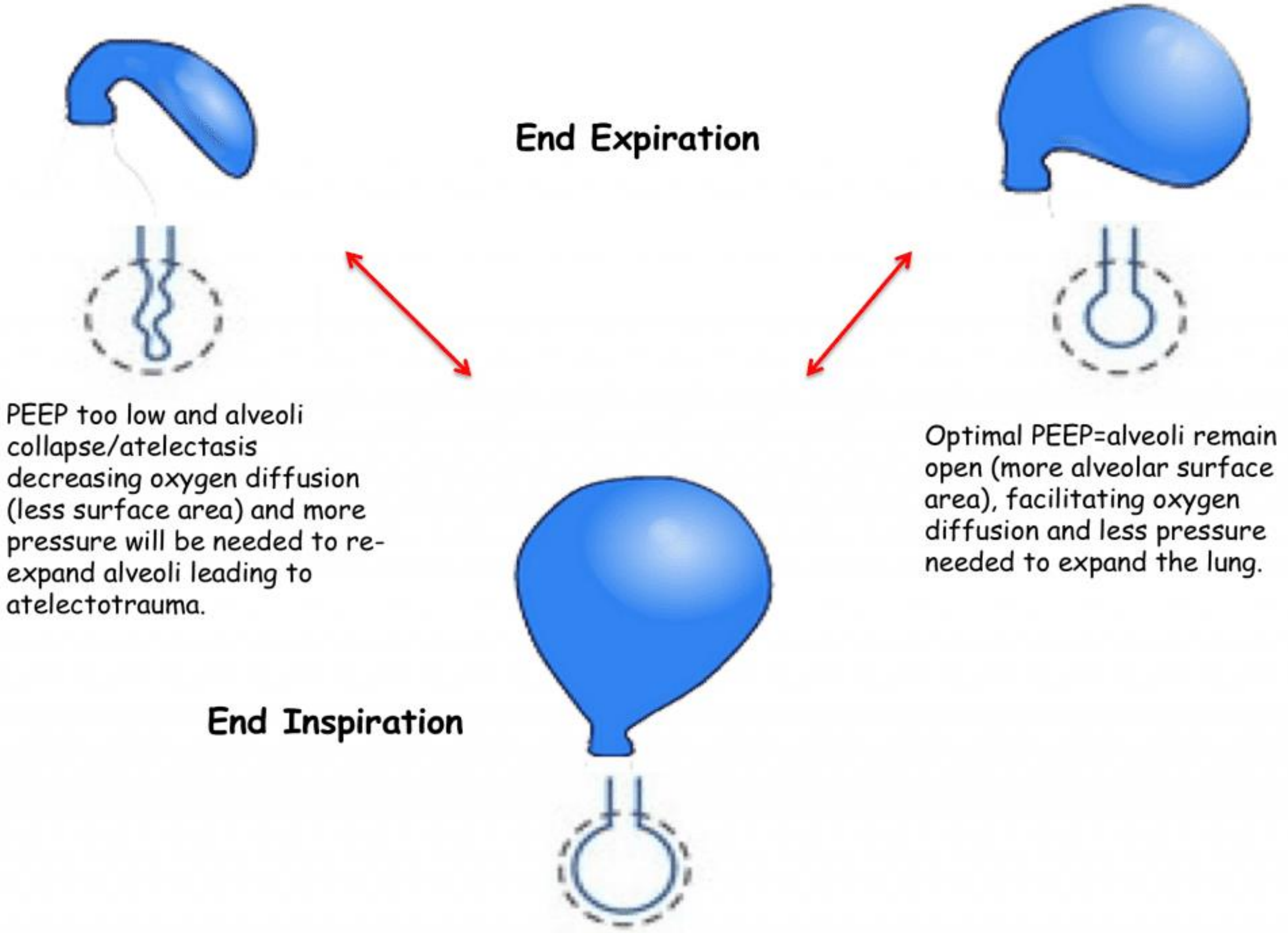


Fig. 3. Extended compliance or lung expansion curve (Adopted from Goldsmith et al.).


End Expiration
PEEP too low and alveoli collapse/atelectasis decreasing oxygen diffusion (less surface area) and more pressure will be needed to re-expand alveoli leading to atelectotrauma.
Optimal PEEP=alveoli remain open (more alveolar surface area), facilitating oxygen diffusion and less pressure needed to expand the lung.
End Inspiration

How to set PEEP

- If FRC is expected to be:
  - normal: 3-4 cms
  - moderately reduced: 4-5
  - severely reduced: 5-7
- Exceptionally, if hyperinflation & auto-PEEP are expected
  - choose 2.5

Low
(2-3 cm)

Medium
(4-7cm)

High
(>8cm)

Flow

- Modern ventilator auto regulated flow
- High requirement in case of leak
- Increasing flow converts Sign wave to square wave hence increases MAP
- Choices are between 4- 10 L/min
- Depends on
  - minute ventilation (flow > 3 x M.V.)

Assisted ventilation of the neonate, Sixth edition, 2017

FiO2

- Simplest parameter to improve oxygenation

- Only to keep SpO2 90 to 95%

- PaO2 50 to 80 mmHg

- Improve lung recruitment before increasing the FiO2

- FiO2 >0.6 increases the risk of oxytrauma

Assisted ventilation of the neonate, Sixth edition, 2017

Conventions

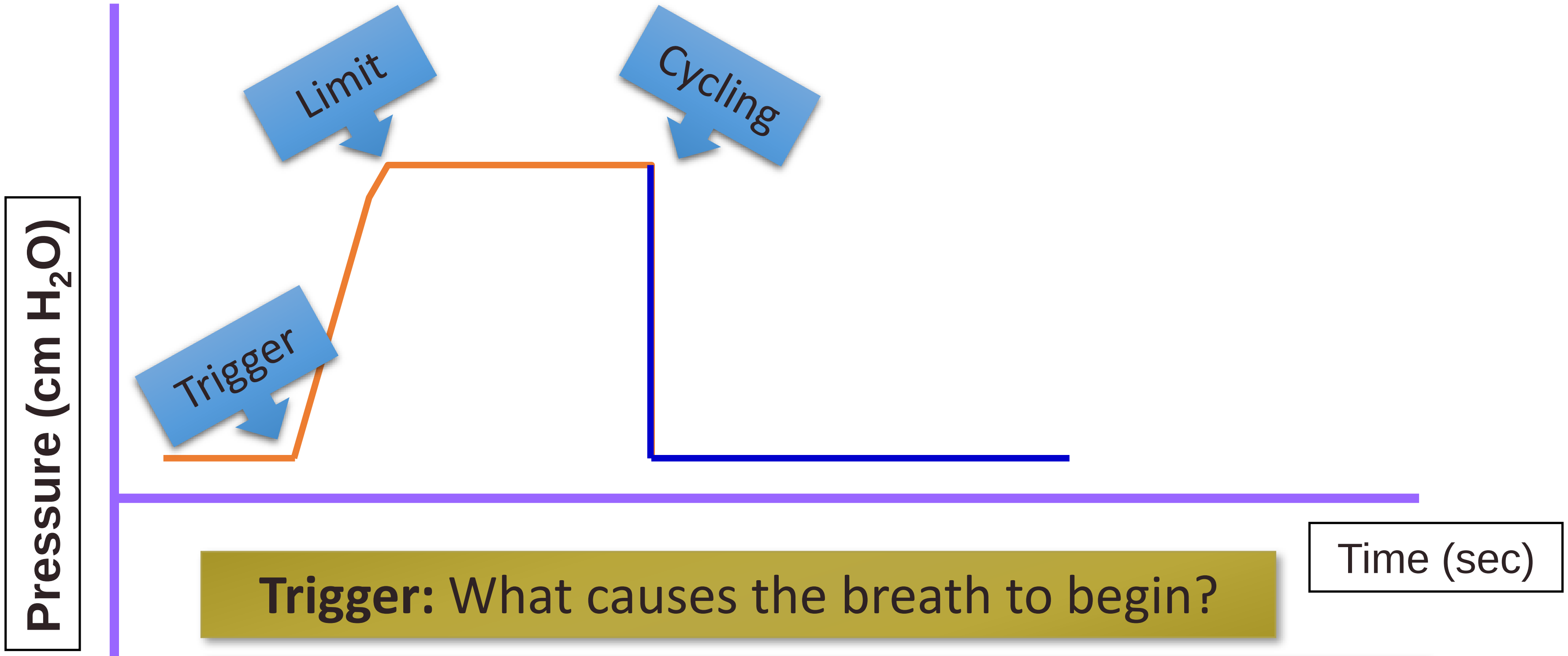
PIP / PEEP x FiO2% @ RR x Ti

16/4 x 50% @ 40 x 0.35

Ranges

PIP:	12 - 25 cms	RR:	20 - 60
PEEP:	3 - 8 cms	Ti:	0.3 - 0.5
FiO2:	21 - 100%	Flow:	4- 10

Terminology



Trigger: What causes the breath to begin?

Limit: What regulates the gas flow during breath?

Cycling: What causes the breath to end?

Assisted ventilation of the neonate, Sixth edition, 2017

What happens in apnea?

- Either central cessation or obstruction of major airway
- Lungs are normal
  - needs room air
  - physiological PEEP
  - PIP to provide 5 ml/kg T.V.
  - enough rate to give back-up
  - Ti = 3 x TC of a normal lung

    3 x R (cm/ ml/sec) x C (ml/cm)

    3 x 30 x 0.005

    3 x 0.15

    0.45 sec

What happens in RDS?

- Surfactant deficiency
  - Low FRC
  - Low compliance
- Premature
  - High chest wall compliance
  - Airways collapse easily

Initial settings

Disease	PIP	PEEP	Ti	Te	VR	FiO2
Mod. RDS	18-20	4-5	0.4	0.8	40-50	0.5
Severe RDS	23-25	5	0.3	0.7-0.8	50-60	0.8-0.9
Apnea of premat-urity	12-14	3-4	0.4-0.5	1-1.2	20-30	0.21-0.3
MAS	16-20	3-5	0.4-0.5	1.0	30-40	0.8-0.9

LET’S QUIZ

CASE:A 28 week gestation, 1000 grams, 3 day old neonate ventilated on SIMV

-Pressure:16/5

-Fio2: 70%

-RR:60/min

-MV:0.12 L/min

Saturation:85%

- ABG:

  pH:7.23

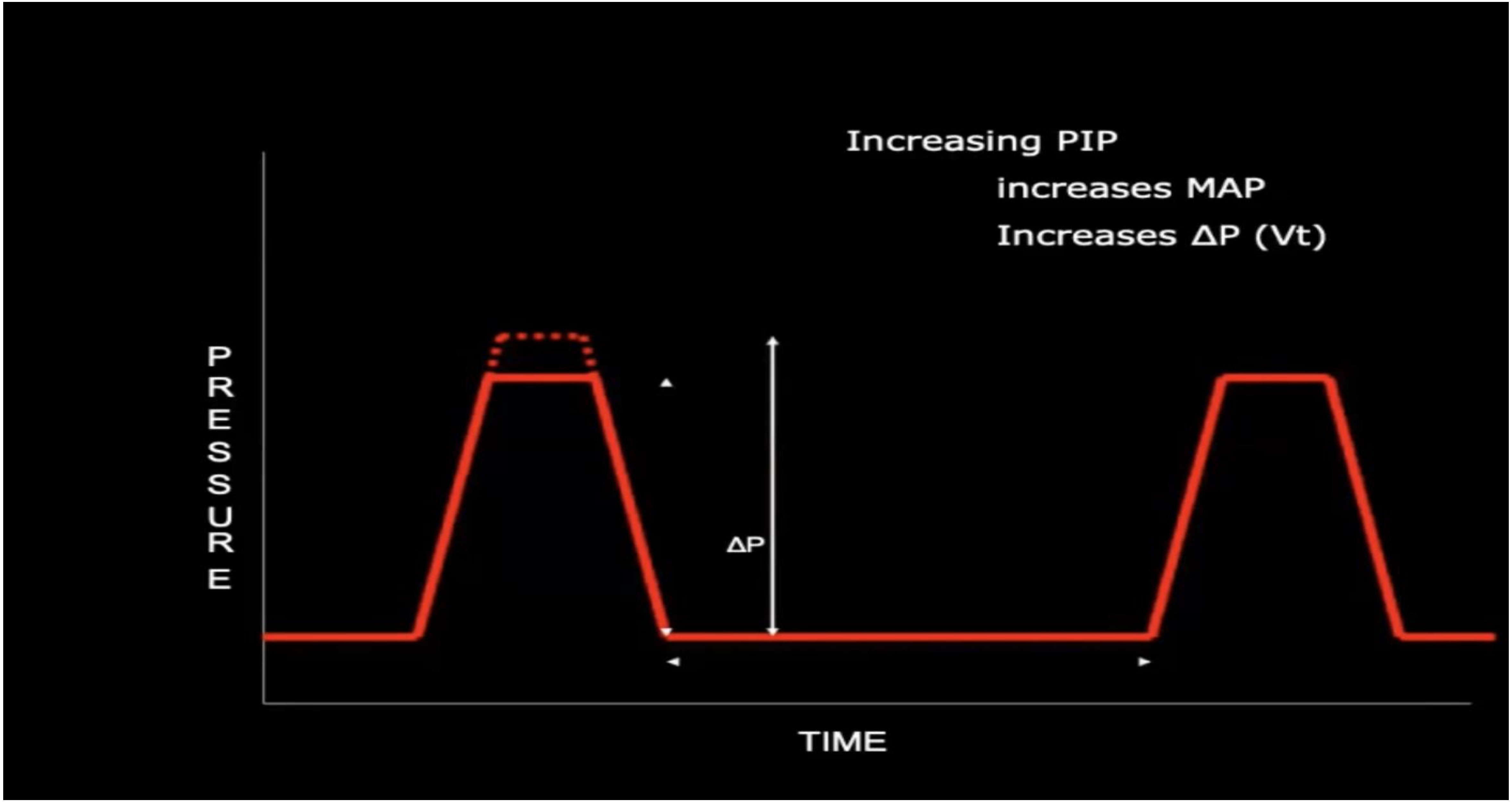
  pO2:39

  pCO2:68

  BE:-3

Solution?

1. **Increase FiO2**
2. **Increase PIP**
3. **Increase PEEP**
4. **Increase RR**
5. **Increase Flow**

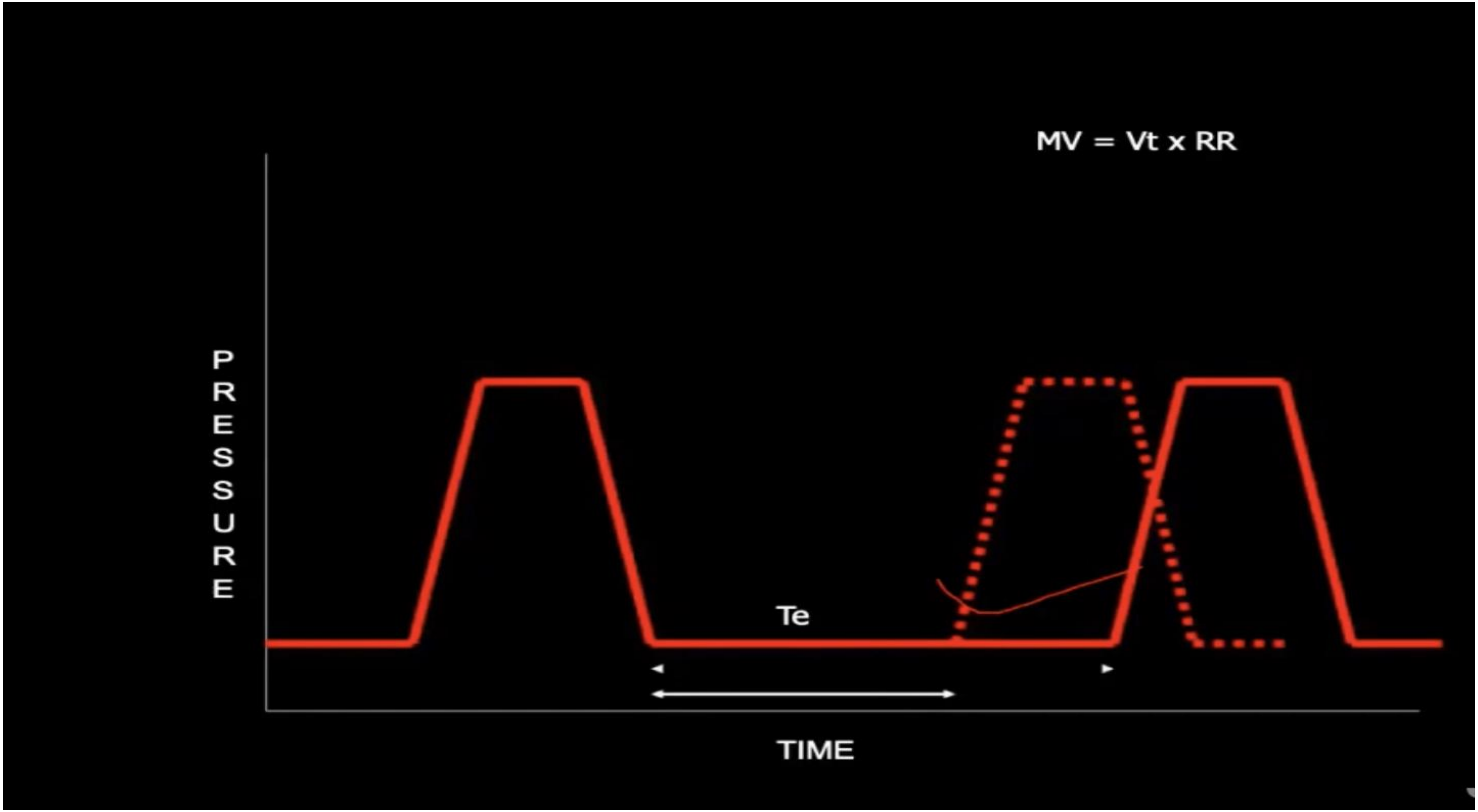

Increasing PIP
increases MAP
Increases ΔP (Vt)
PRESSURE
ΔP
TIME

Case:25 week gestation, 500gms,4 day old

- Ventilated :on SIMV
  - Pressure:20/5
  - FiO2:24%
  - RR:40/min
  - MV:0.08L/min
  - Saturation:92%
- ABG:
  - pH:7.2
  - pO2:64
  - pCO2:70
  - BE:-2

Solution?

1. Increase RR
2. Increase PIP
3. Increase PEEP
4. Decrease PEEP
5. Increase Flow


MV = Vt x RR
PRESSURE
Te
TIME

What did we learn?

- ❑ Lung characterstics depend on
  - Compliance
  - Resistance
  - Time constant
- ❑ Oxygenation depends on
  - PIP
  - PEEP
  - Ti
  - Flow
  - Fio2
- ❑ CO2 removal depends on
  - Vt
  - RR


Thank you
gettyimages
cdwheatley
185056652