Basic Terms & Concepts of Mechanical Ventilation

Chapter 2

Spontaneous Ventilation

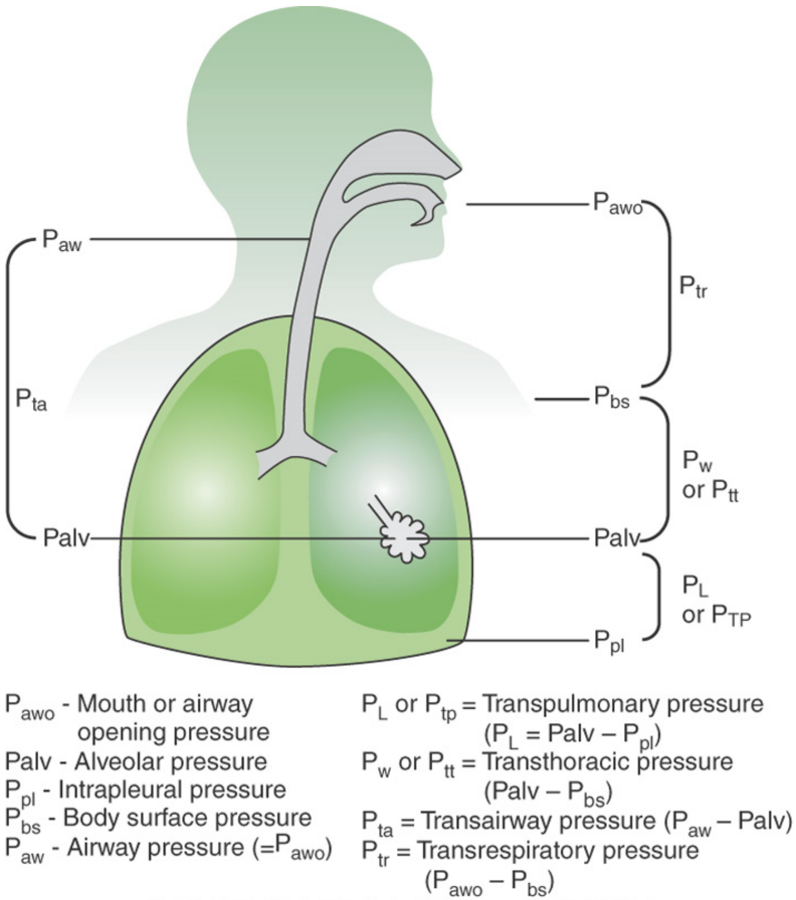
- Movement of air in and out of the lungs
- Muscles of inspiration contract – expand the thorax
- Passive exhalation
- Air flow due to pressure gradients – high to low pressure
- No gas flow present when pressures across the gradient are equal

Respiration

- Movement of gas molecules across a membrane
  - Internal – cellular level
  - External – a-c membrane

Pressure Equivalents

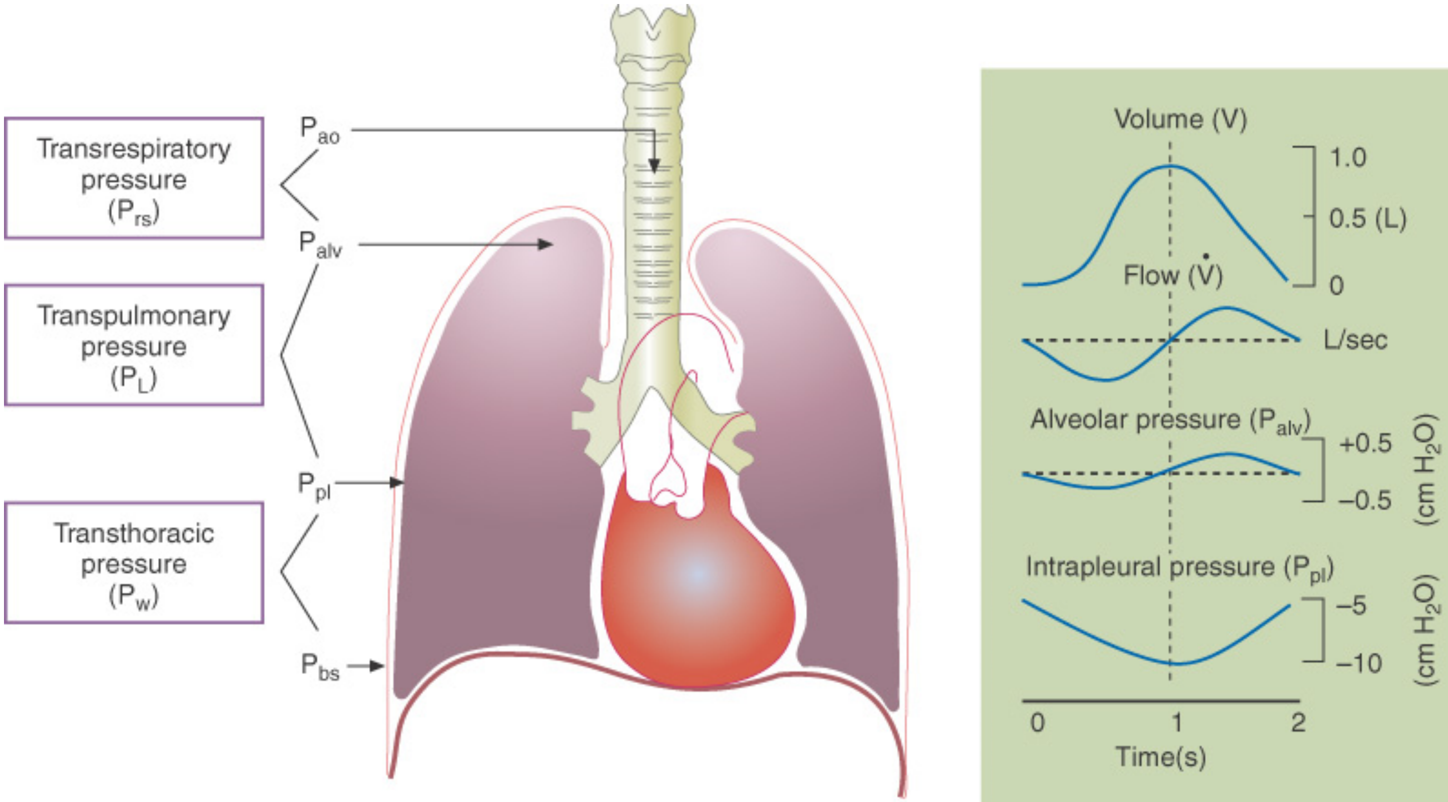
- Ventilating pressures use cmH2O
- 1 mmHg = 1.36 cmH2O
- Pressures are referenced from atmospheric pressure – baseline value of zero
- May also see kilopascals used 1kPa = 7.5mmHg (SI units)



(From Wilkins RL, Stoller JK, Scanlan CL: *Egan's fundamentals of respiratory care*, ed 8, St Louis, 2003, Mosby.)

- P_{awo}: zero*
- P_{bs}: zero*
- P_{pl}: -5cmH2O -10cmH2O
- P_{A}: +1cmH2O -1cmH2O

*unless pressure applied

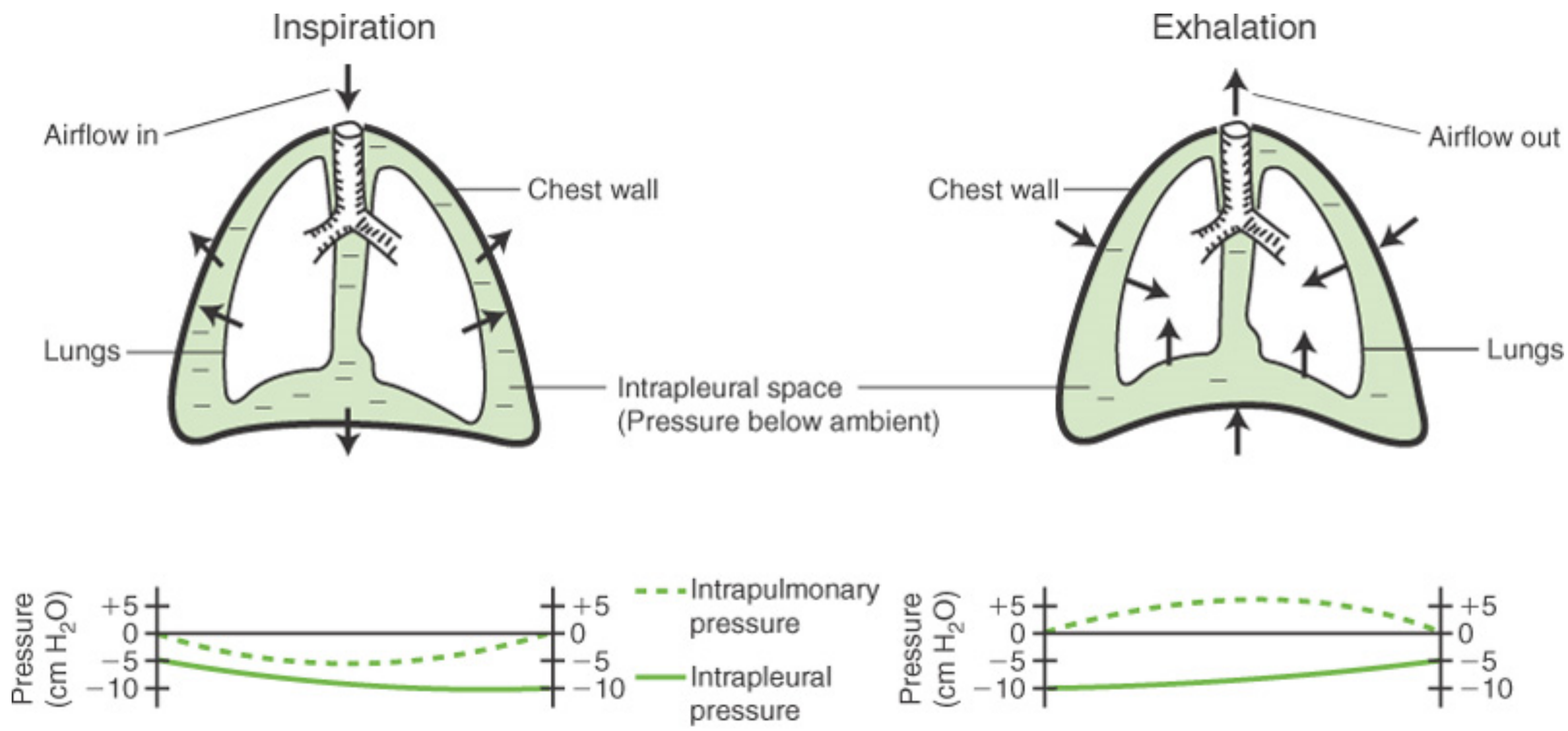

Transrespiratory pressure (P_{rs})
Transpulmonary pressure (P_L)
Transthoracic pressure (P_w)
P_{ao}
P_{alv}
P_{pl}
P_{bs}
Volume (V)
1.0
0.5 (L)
0
Flow ($\dot{V}$)
L/sec
Alveolar pressure (P_{alv})
+0.5
–0.5
(cm H_2O)
Intrapleural pressure (P_{pl})
–5
–10
(cm H_2O)
0
1
2
Time(s)

Pressure Gradients Matching

- Transairway Pressure
- Transthoracic Pressure
- Transpulmonary Pressure
- Transrespiratory Pressure

1. $P_A - P_{bs}$
2. $P_{aw} - P_A$
3. $P_A - P_{pl}$
4. $P_{awo} - P_{bs}$

Mechanics of Spontaneous Ventilation



Lung Characteristics: Compliance

- Relative ease with which a structure distends
  - opposite of elastance
- Used to describe the elastic forces that oppose lung inflation
- $\triangle V / \triangle P$ = L/cmH2O
- 50-170ml/cmH2O normal
- 35/40 -100ml/cmH2O intubated patient
- Static Compliance
- Dynamic Compliance

Clinical Rounds 2-1

If compliance is normal at 0.1L/cmH2O, calculate the amount of pressure needed to attain a tidal volume of 0.5L (500ml).

$\triangle P = \triangle V / C$

$0.5/0.1 = 5$ cmH2O

A Palv change of 5cmH2O would be needed to achieve a 0.5L tidal volume in a person with normal lung compliance.

Lung Characteristics: Resistance

- Frictional forces associated with ventilation
  - Anatomic structures
  - Tissue viscous resistance
- Ability of air to flow depends on
  - Gas viscosity
  - Gas density
  - Length and diameter of the tube
  - Flow rate of the gas through the tube
- Raw = P_{TA}/flow cmH2O/L/sec
  - $P_{TA} \approx$ PIP – Pplat
  - Assumes constant flow
- Normal 0.6-2.4 cmH2O/L/sec
- Intubated patients 5-7cmH2O/L/sec (and higher!)

Clinical Rounds 2-2

An intubated 36y.o. woman is being ventilated with a volume of 0.5L (500ml). The PIP is 24cmH2O, Pplat is 19cmH2O and the baseline pressure is zero. The inspiratory gas flow is constant at 60L/min (1L/sec). What are the static compliance and airway resistance? Are these normal values?

Compliance : 500/19 = 26.3ml/cmH2O

Raw: 24-19/1 = 5cmH2O/L/s

The patient's compliance is very low, suggests that some condition is making the lungs stiffer

Raw is low considering the presence of an artificial airway

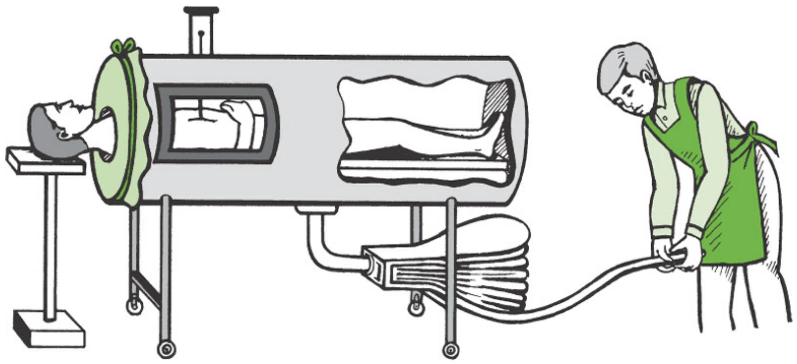
Time Constants

- Heterogeneous not homogeneous lungs
- Representation of passive filling and passive emptying
- Differences in compliance and resistance affect how rapidly the lung units fill and empty
  - Normal lung units fill within a normal length of time
  - Decreased compliance – stiff lung units fill rapidly
  - Increased airway resistance – narrow airways cause slow filling
- Time constant = compliance x resistance
- Important for setting inspiratory time and expiratory time

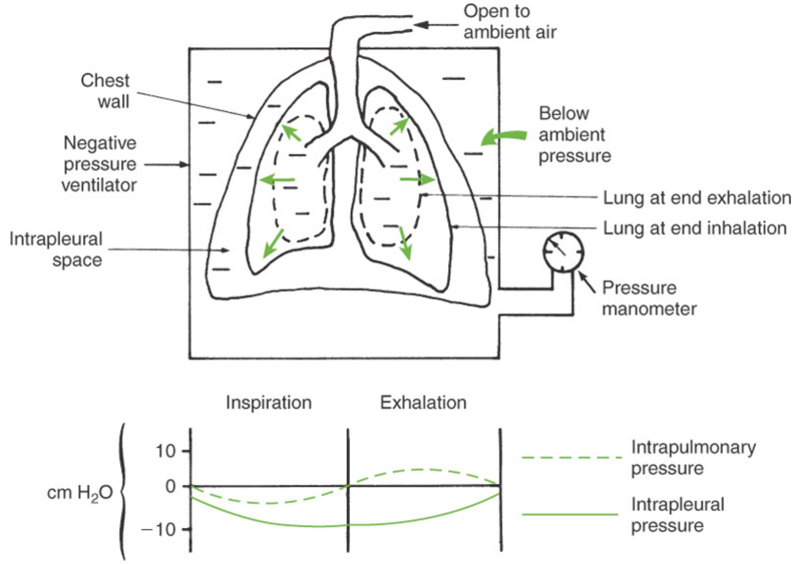
Types of Ventilators

- Negative Pressure
- Positive Pressure
- High Frequency

Negative Pressure Ventilators



(Redrawn from Young JA, Crocker D: *Principles and practices of inhalation therapy*, St Louis, 1970, Mosby.)



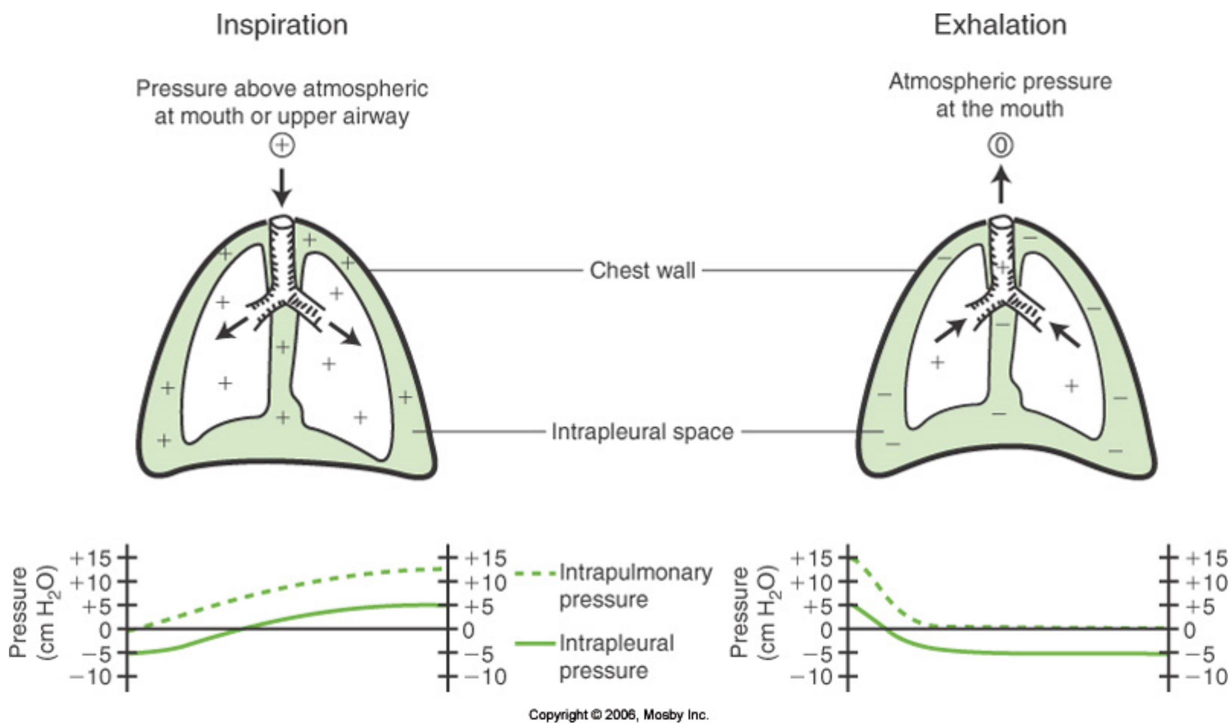
- Attempts to mimic normal physiology
- Types:
  - Iron lung – tank ventilator
  - Chest cuirass
- Maintained without the need for ETT, tracheostomy, able to talk and eat
- Cardiovascular concerns, access to patient

High Frequency Ventilation

- Above normal ventilating rates with below normal ventilating volumes
- HFPPV
- HFJV
- HFOV

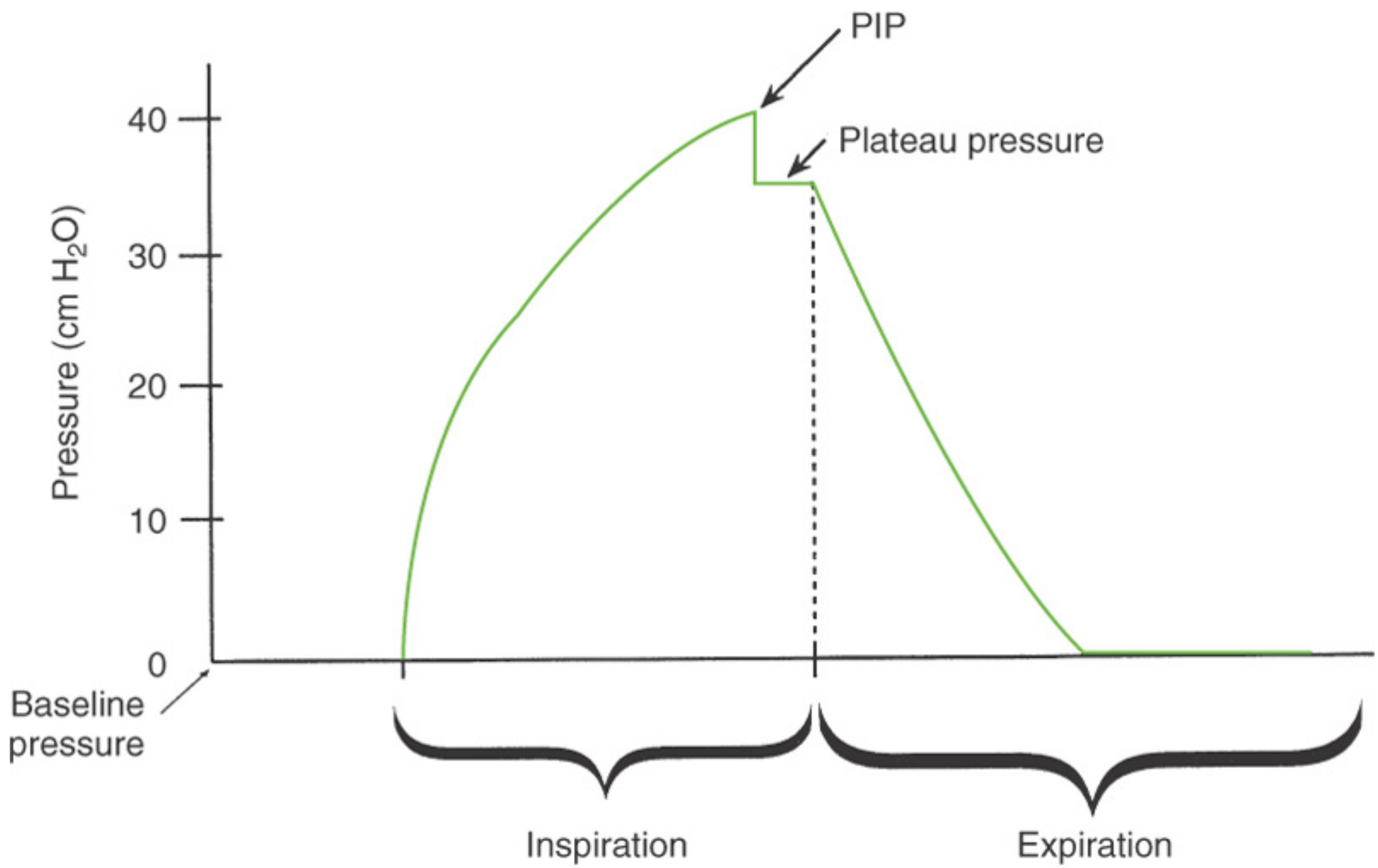
Positive Pressure Ventilators

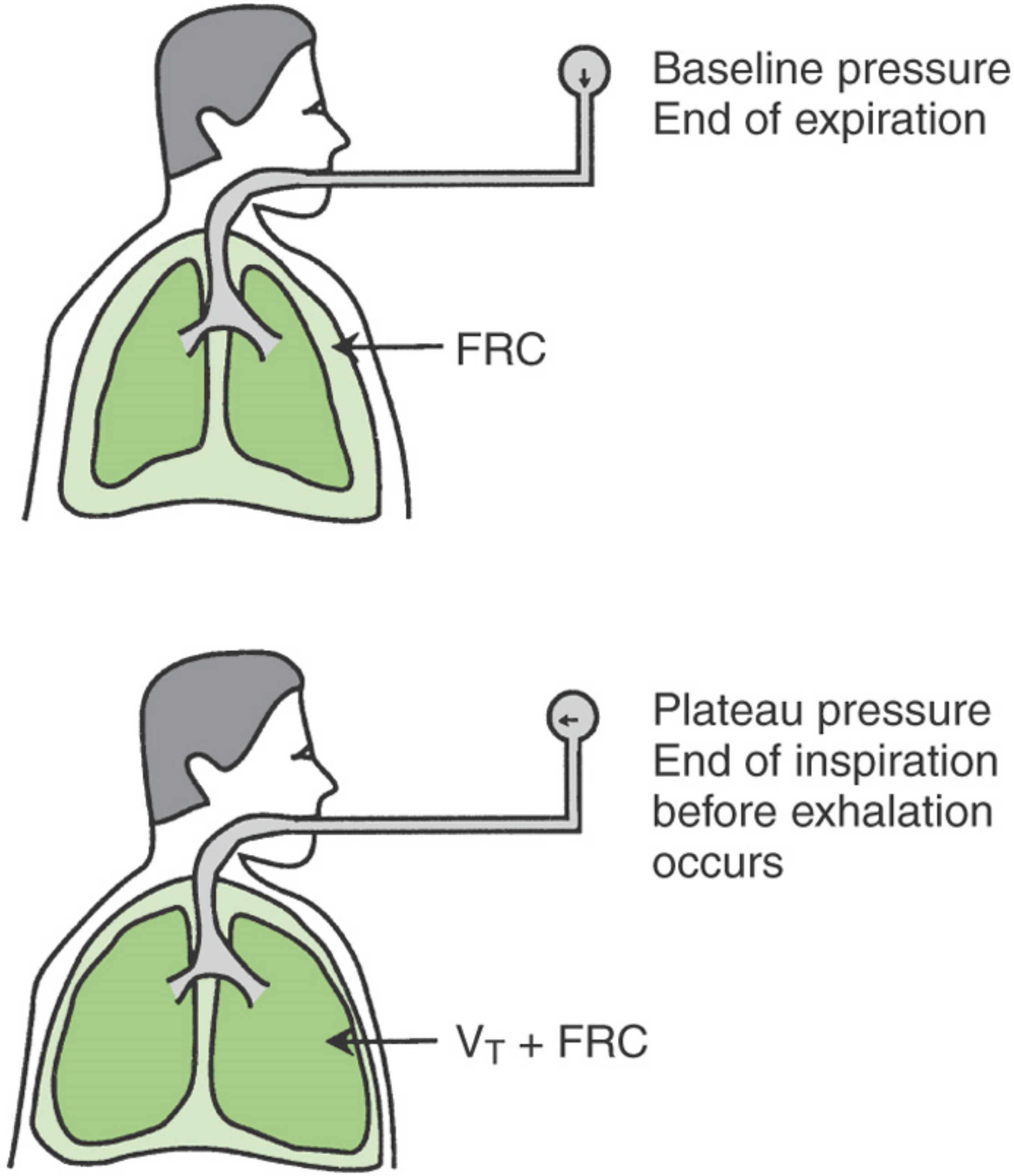
- Requires airway interface
- Applies pressure to create gradient between mouth and lung

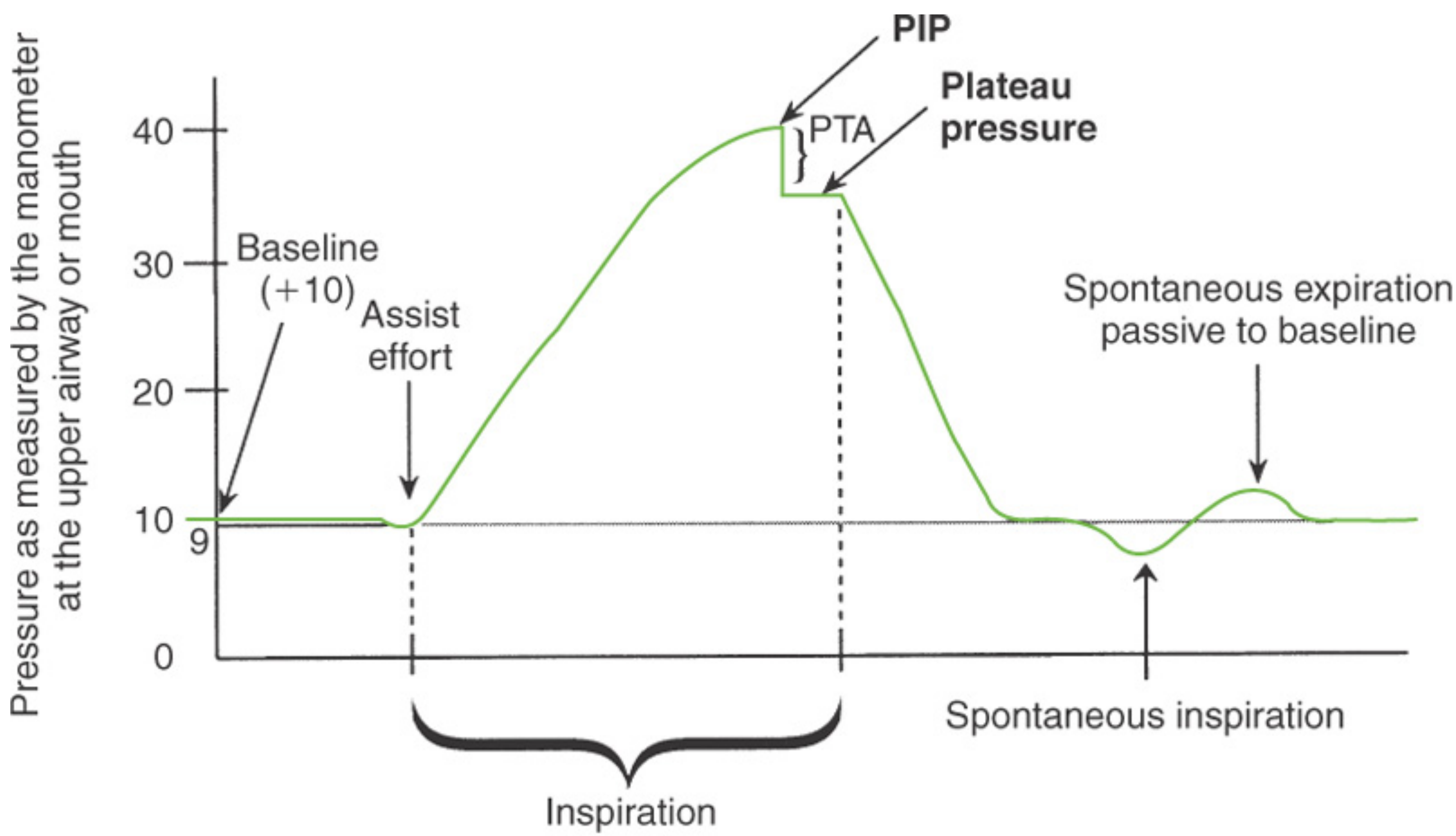


Pressure Measurement

- Manometer – pressure gauge
- Pressure points graphed over time during the breath cycle
- Used to:
  - Monitor patients
  - Describe modes of ventilation
  - Calculate a variety of parameters
- Baseline/End expiratory pressure
- Peak
- Plateau


PIP
Plateau pressure
40
30
20
10
0
Pressure (cm H_2O)
Baseline pressure
Inspiration
Expiration


Baseline pressure
End of expiration
FRC
Plateau pressure
End of inspiration
before exhalation
occurs
V_T + FRC


PIP
Plateau pressure
PTA
40
30
20
10
9
0
Pressure as measured by the manometer at the upper airway or mouth
Baseline (+10)
Assist effort
Spontaneous expiration passive to baseline
Spontaneous inspiration
Inspiration