Anesthesia Ventilators 101

Featuring the Hallowell 2000

Heidi Reuss-Lamky, LVT, VTS (Anesthesia & Analgesia, Surgery)
Oakland Veterinary Referral Services
Bloomfield Hills, Michigan 48302
hreuss@ovrs.com

Why Ventilate?

- Anesthetic agents are respiratory depressants—

  All anesthetized patients hypoventilate!

  - Difficulty maintaining $PaCO_2$ <40 mmHg

GOAL: Maintaining normal CO_2 tensions in arterial blood

Why Ventilate?

- Hypoventilation / apnea / panting
  - Helps maintain stable anesthesia plane
- Gross obesity / Pickwickian
- Prolonged surgical procedures
  - >90 minutes (especially horses)
- Neuromuscular blockers
- Patient positioning
- Lung disease
- Intracranial disease

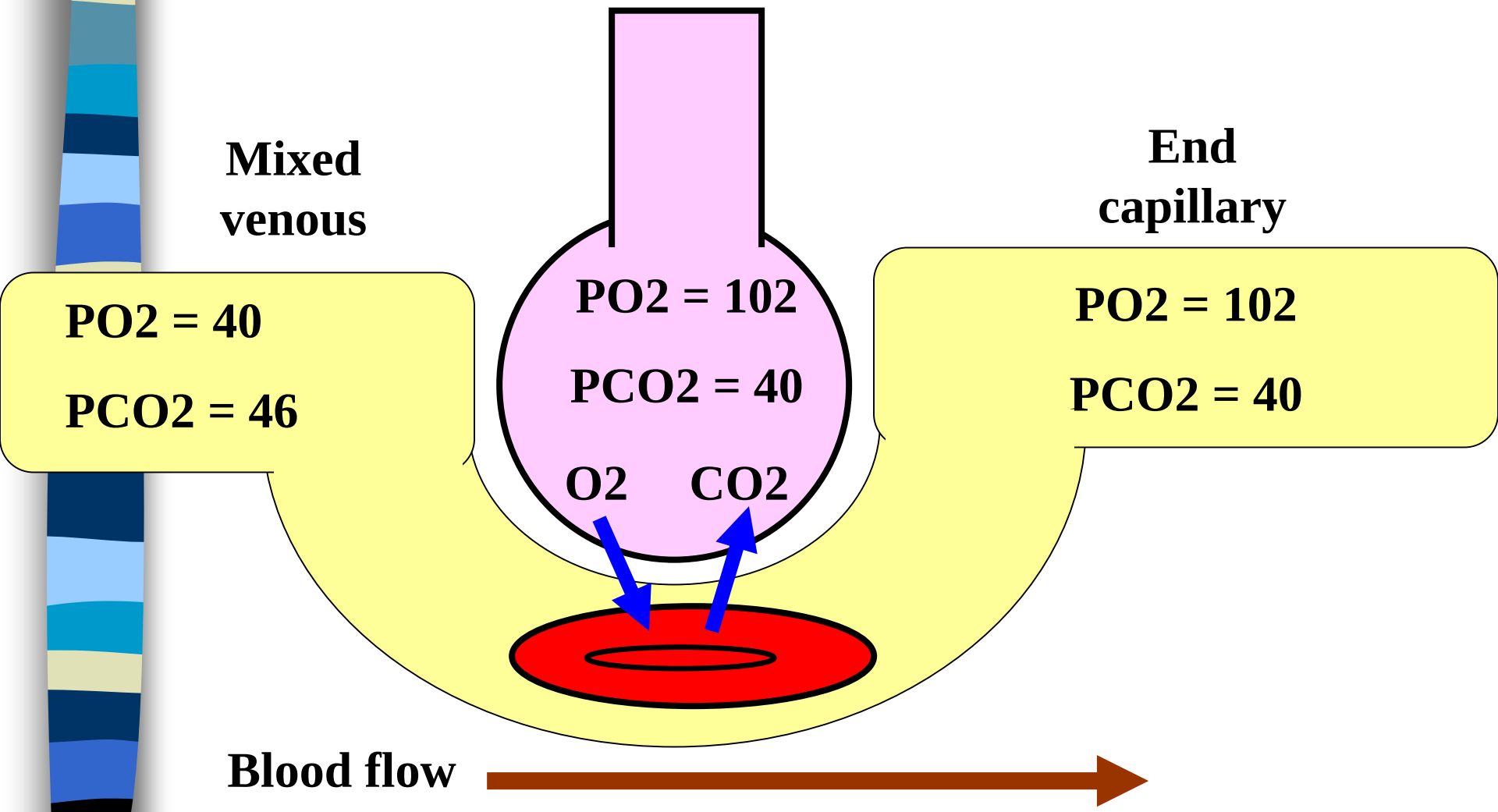
Why Ventilate?

- Thoracic surgery & trauma
  - Flail chest or diaphragmatic hernia
- Convenience!

Carbon Dioxide Physiology

- CO_2 transferred in the body in 3 forms:
  - 60-70% transported as bicarbonate ion
  - 20-30% transported bound to proteins
  - *5-10% dissolved in plasma.
- *Plasma component measured during blood gas analysis as arterial partial pressure of carbon dioxide ($PaCO_2$)

Carbon Dioxide Physiology



Carbon Dioxide Physiology

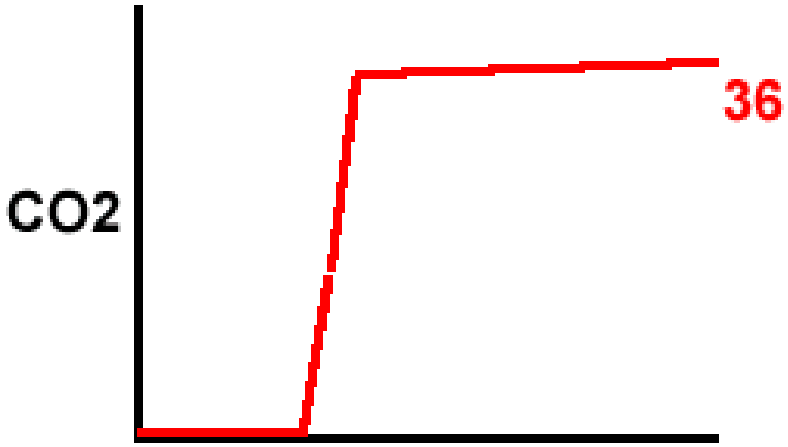
- $ETCO_2$ Requirements
  - Blood flow
  - Cellular metabolism
  - Alveolar ventilation
- Great CPR tool!

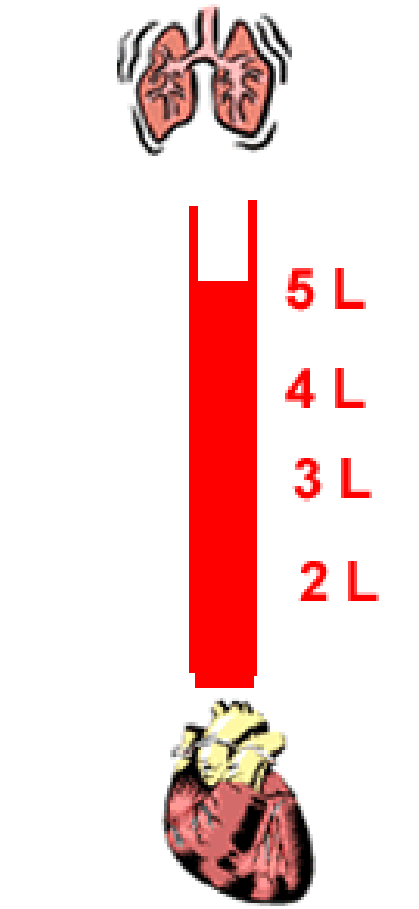
Normal $ETCO_2$ Values

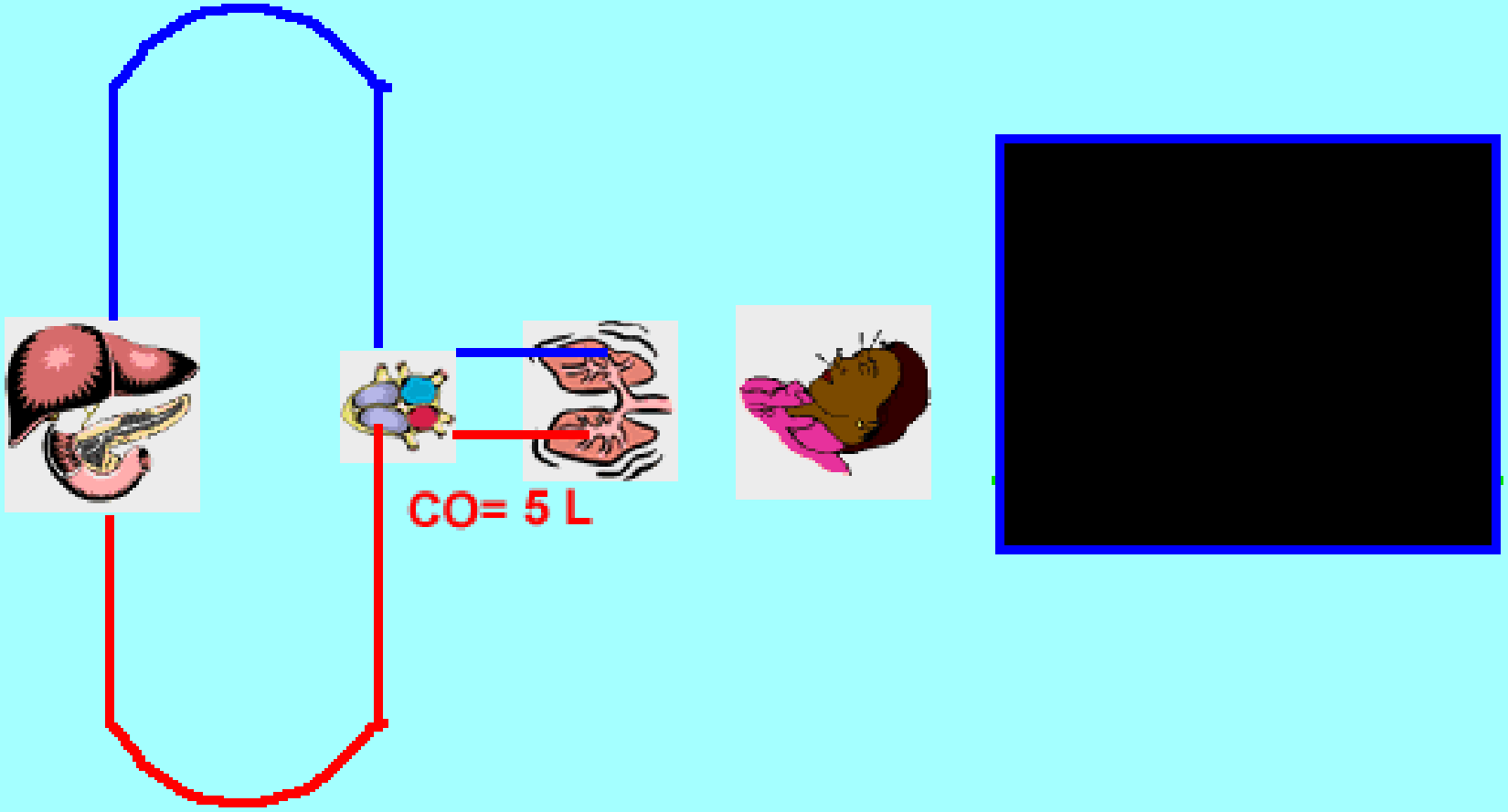
$PaCO_2$	Condition in blood	State of vent
> 45	Hypercapnia	Hypoventilation
35-45	Eucapnia	Normal
< 35	Hypocapnia	Hyperventilation

Carbon Dioxide Physiology

- Assess cardiac output secondary to hypovolemia






CO= 5 L

Carbon Dioxide Physiology… When $EtCO_2 \neq PaCO_2$

- Low pulmonary blood flow
  - Shock / cardiac arrest
- Significant clinical change "delays"
  - Metabolic disorder
  - Pulmonary embolism (V/q)
  - Pneumonia/atalectesis (v/Q)

V/Q CO2

v/Q  CO2

Anesthesia Ventilators

- Double circuit units
  - *Utilize 2 gas sources*

A. Driving gas enters

B. Scavenger

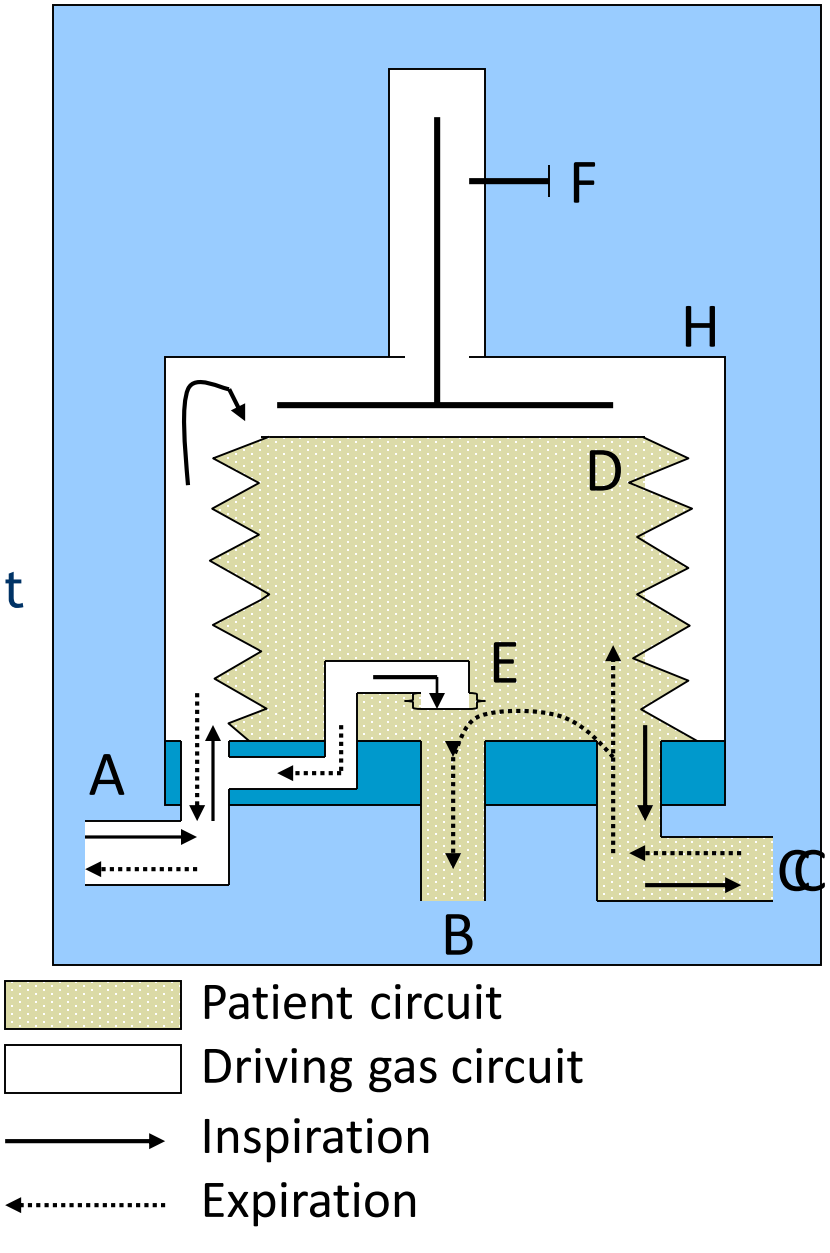
C. Overflow gas from patient circuit

D. Bellows

E. Pop-off valve

F. Tidal volume adjustment

H. Bellows housing



Ventilator Terminology

- **Tidal volume (V_T)-** amount of gas exchanged in one respiratory cycle

- **Minute volume (V^m)-** total amount of gas (in liters) exchanged per minute
  - **Dependent on V_T & breaths per min(BPM):**

$$V_T \text{ X } BPM = V^m$$

Ventilator Terminology

- **IPPV / IPPB:** Intermittent positive pressure (PP) maintained during inspiration; passive expiration

  Anesthesia machines are *intermittent dosing devices…?*

- **PEEP:** Positive end-expiratory pressure
  - Hallowell vents maintain 5 cm H_2O PEEP
  - SurgiVet SAV2500 maintains 2 cm H_2O PEEP

Ventilators Simplified:

=

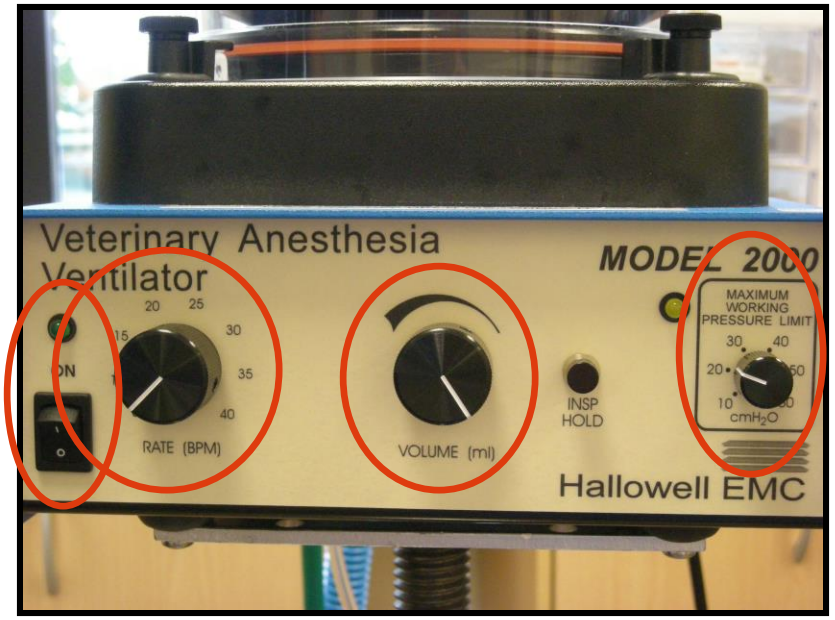
Know Your Equipment!

- Ensure anesthesia machine is equipped for ventilator accessibility

The Front Panel

Four Basic Controls:

- **I/O Power Switch:** Green light above switch indicates ventilator is ON
- **Rate (BPM):** Set respiratory rate in breaths per minute
- **Volume (ml):** Control volume (size) of breath being delivered

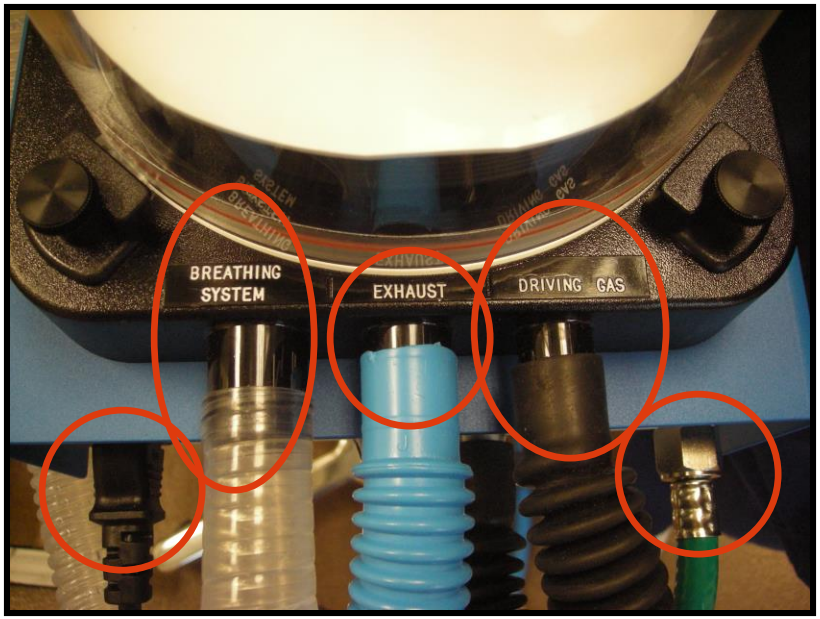


- **Maximum Working Pressure Limit (MWPL):** Set an upper limit above which pressure should not exceed during cycle
  - Set between 20-30 cm H_2O

Ventilator Connections

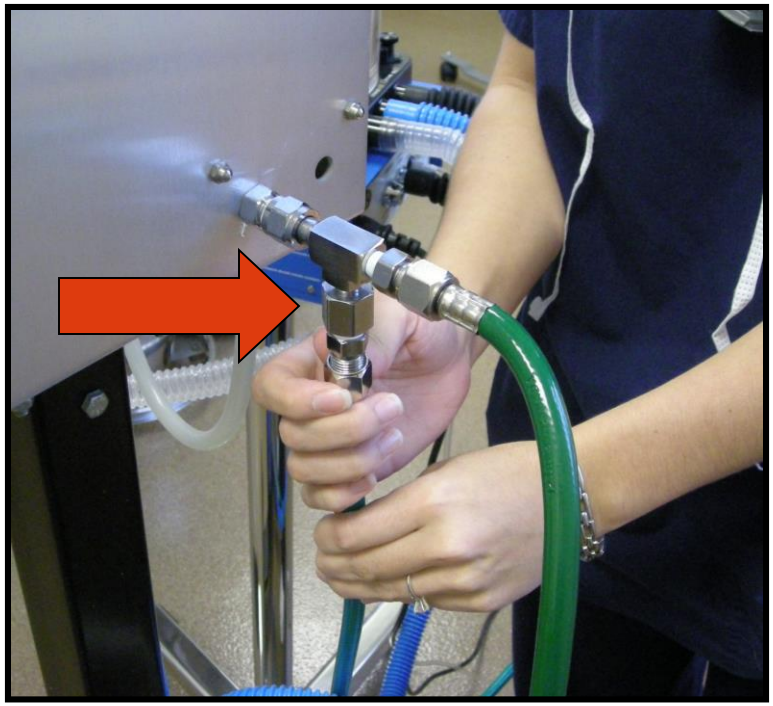
Ventilator parts:

- **Power Plug**
- **Breathing System:** Clear hose
- **Exhaust:** Blue hose
- **Driving Gas:** Black hose
- **O_2 Hose:** Green hose



Connect Oxygen Supply

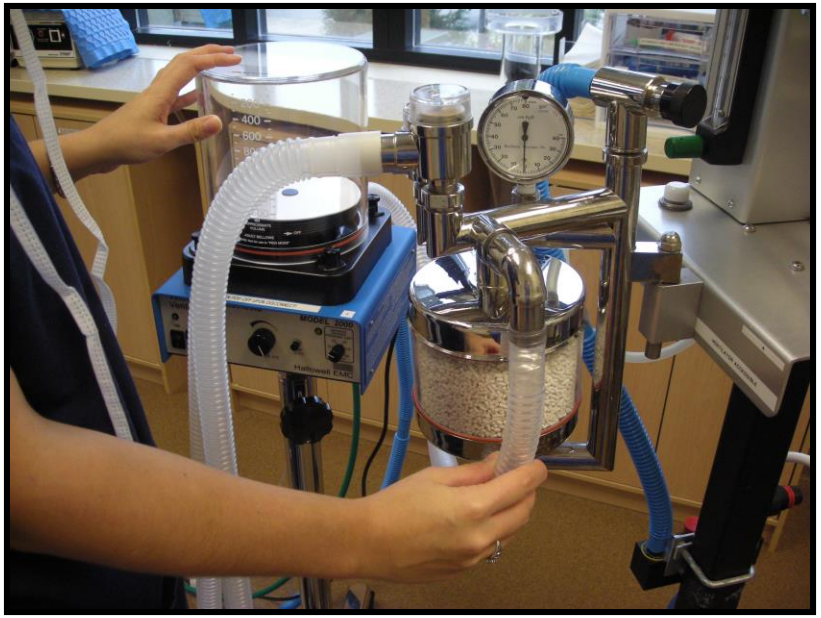
- Additional oxygen connection needed on anesthesia machine to allow ventilator access
- Attach ventilator's loose oxygen hose to open connection



- Tighten oxygen hose to secure
  - Hissing sounds occur when O_2 plugged in to supply tanks!

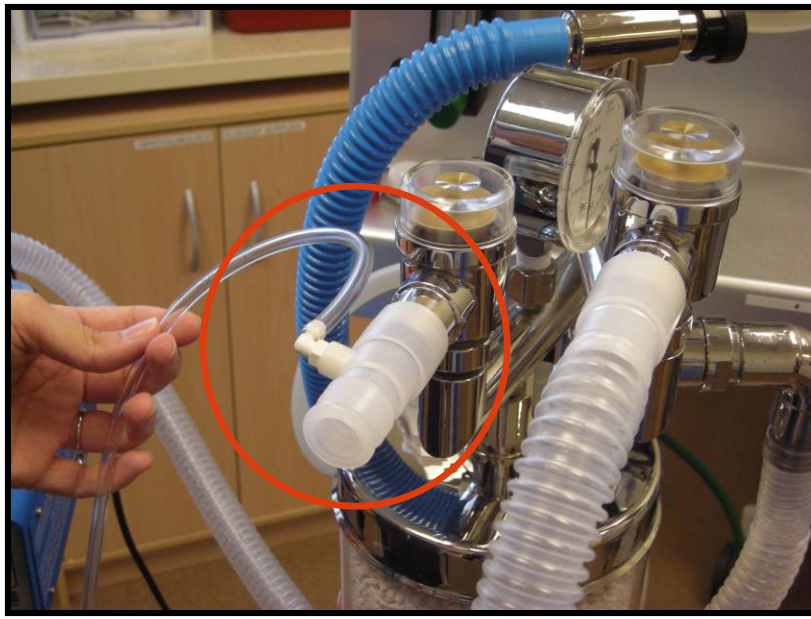
Connect Breathing System

- Follow clear hose (labeled BREATHING SYSTEM) from back of ventilator to unconnected end
- Connect hose to re-breathing bag connection on anesthesia machine
- Ventilator is now a ‘re-breathing bag’



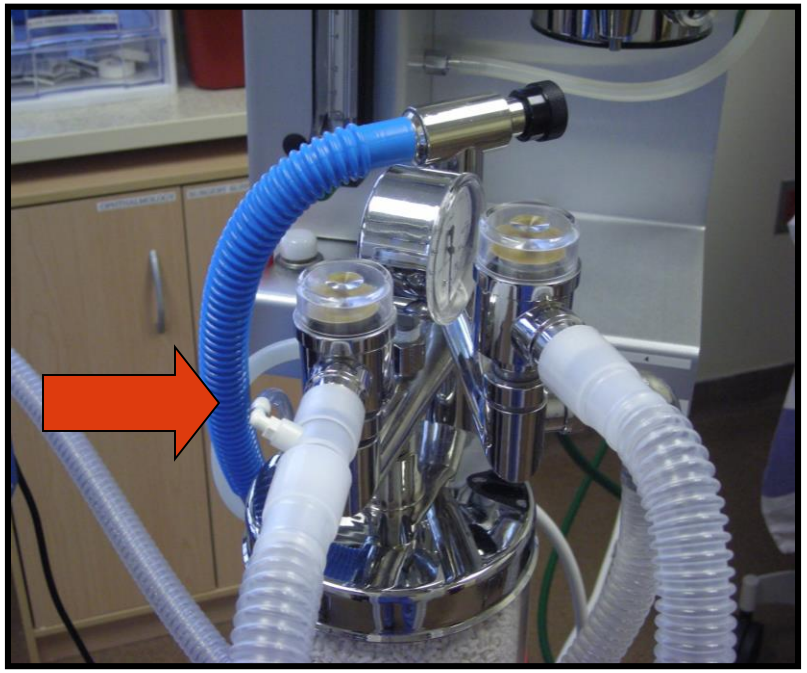
Insert Airway Pressure Sensor

- Connect APST tube to **INSPIRATORY** side of breathing system
  - Small, clear tube connected to a larger male/female connector
  - Confirm inspiratory side with oxygen flush



Connect Wye Hoses

- Attach wye hoses as usual
- APST is now connected between wye hose and anesthetic machine on the **INSPIRATORY** side



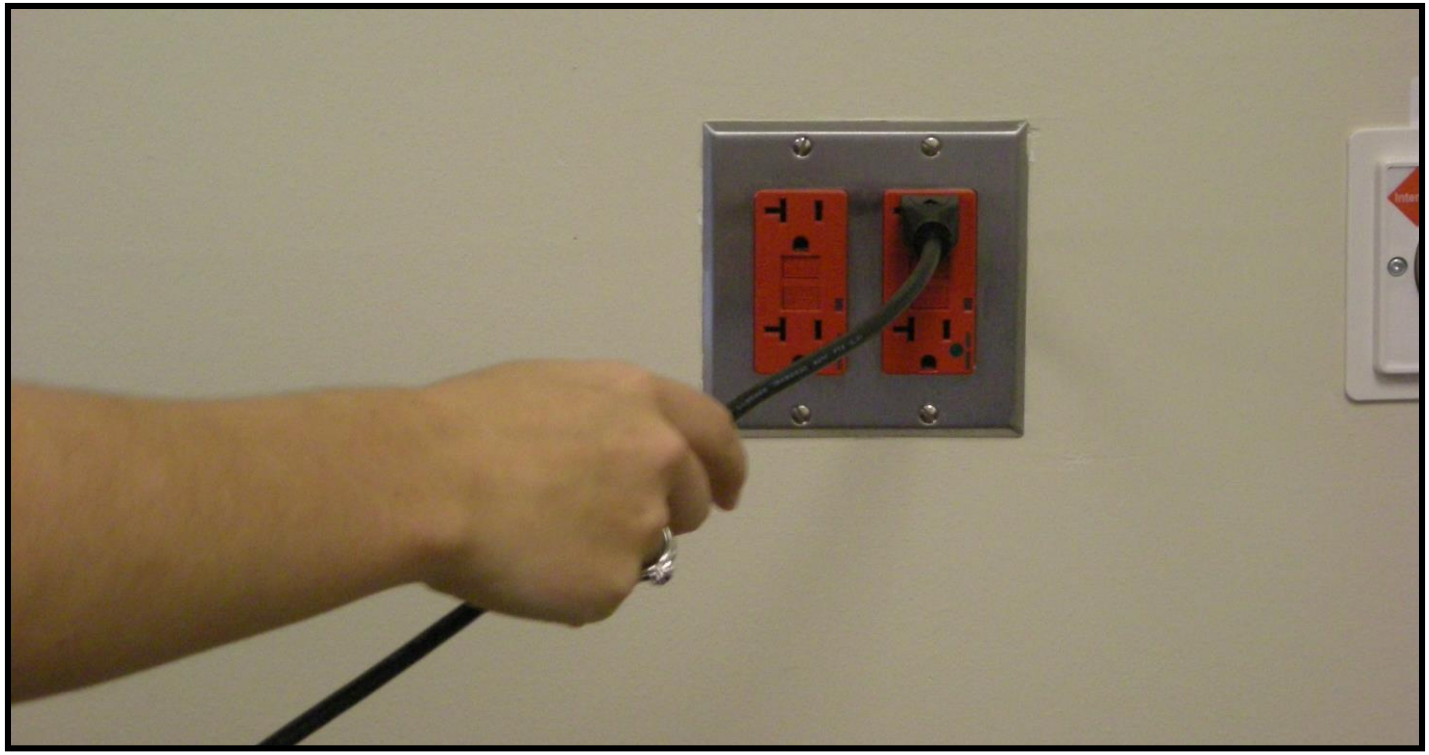
Connect Exhaust

2 Options:

- Remove existing scavenging hose
- Connect scavenger to (2nd) open port
  - Remove red cap from port opening first

Plug It In!

- Don’t forget to plug power cord from ventilator into a wall outlet

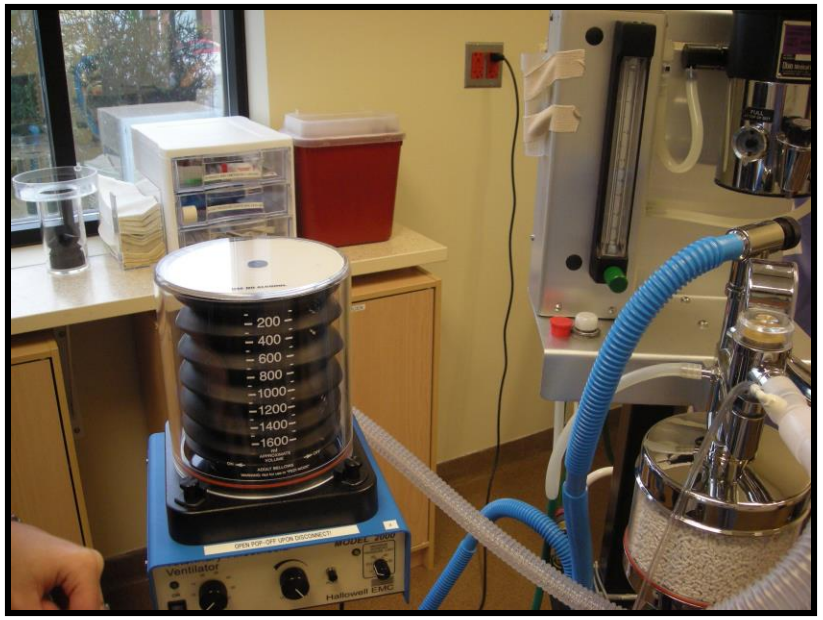


Pop-off Valve

- *Close* pop-off valve once ventilator is connected to anesthesia machine
  - Prevents leaks
- It is ***very*** important to remember to OPEN pop-off valve once ventilator is disconnected!

Check for Leaks

- Occlude end of wye hose
- Turn on oxygen until bellows is completely inflated
- Turn off O_2
- Bellows will stay inflated if no leaks present



Anesthesia machine should be checked for leaks both ***before*** **and** ***after*** connecting ventilator

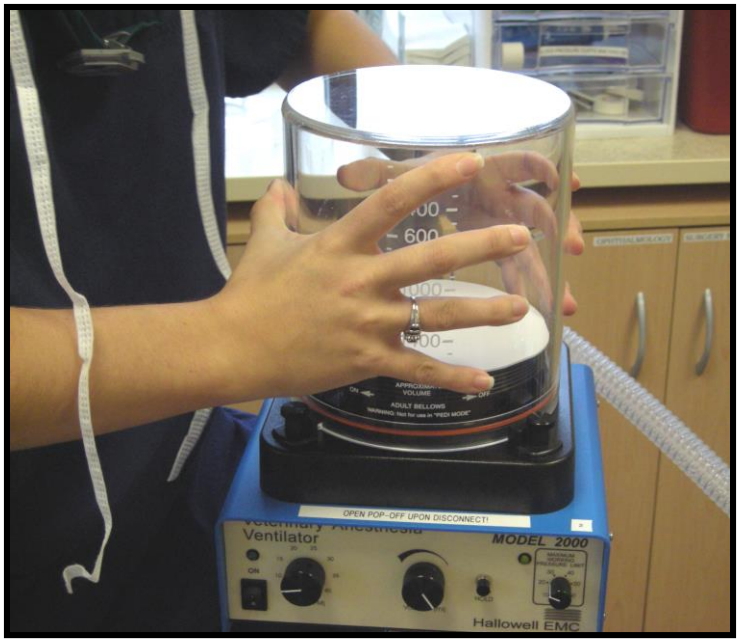
Changing Bellows

- *Rule of thumb:

  <30 lb = small bellows

  >30 lb = large bellows

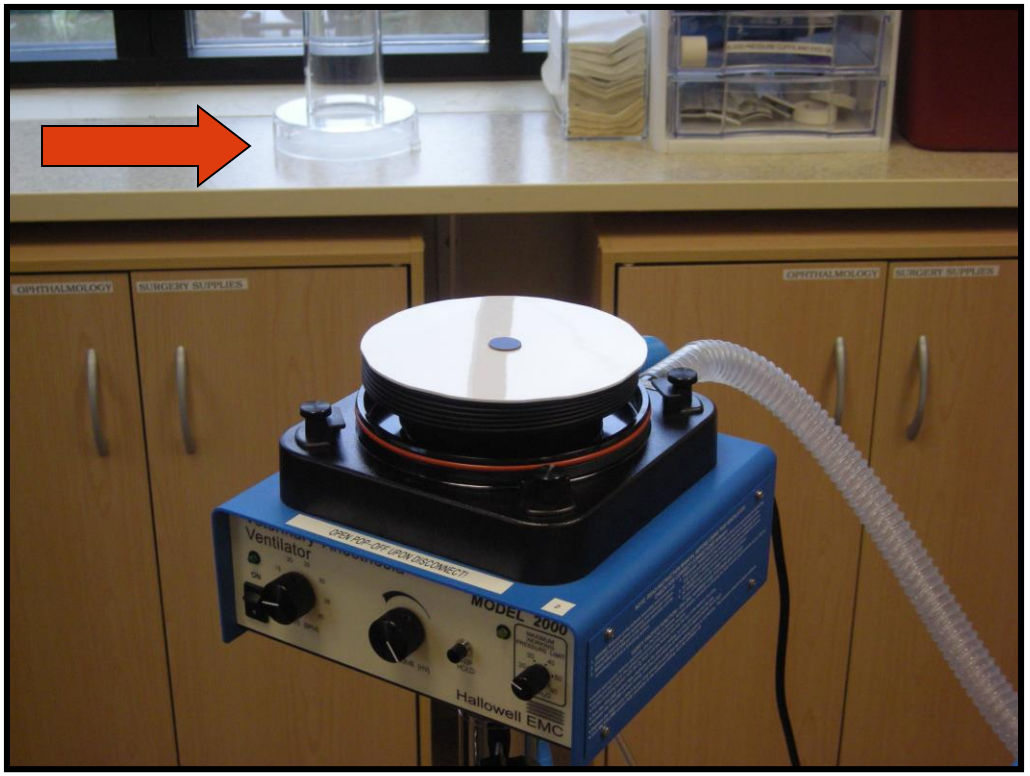
  *LEAN BODY WEIGHT ONLY



- Pediatric bellows: 0-300 ml (0.5-15 kg)
- Adult bellows: ≤1500 ml (up to 75 kg)
- Foal bellows: ≤ 3000 ml (up to 150 kg)

Removing Bellows

- Once removed, put bellows housing in a safe place



Fitting Bellows

- Small bellows fits seated onto smaller (inner) ring
  - Large bellows requires outer ring
- Ensure bellows placed on ventilator *circumferentially*
  - Only very bottom of accordion should be attached to ventilator

- **Misplacement will prevent bellows from fully inflating

Setting Bellows

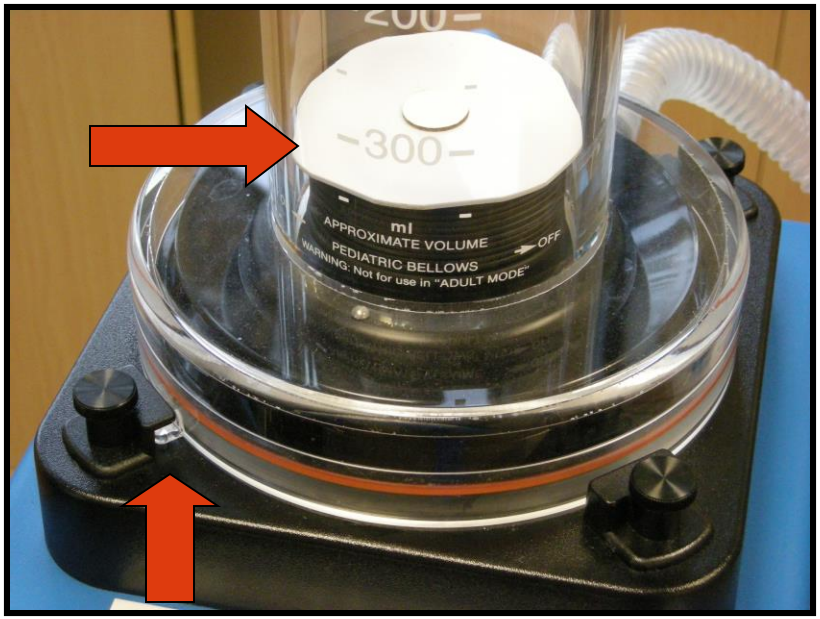
- Ensure correct placement by gently lifting bellows until last accordion ring is visualized in place
  - Eliminate concaved or folded areas in bellows

Secure Bellows Housing

- Replace corresponding bellows housing
- Firmly secure housing
- Turn only base of housing (not tall area) to avoid damage

Secure Bellows Housing

- Once housing is firmly set, rotate clockwise until housing is locked
  - If housing unit is not properly set, cracked or damaged, a leak may result



- Ensure that volume numbers are visible and facing front of anesthesia machine

Set Maximum Working Pressure Limit (MWPL)

- Typically 20-30 cm H_2O
- Safety feature!

Peak Inspiratory Pressure (PIP)

- Lung compliance is important for determining adequate pressure to inflate the lungs

  (volume/pressure/kg)

- PIP should be between 12 to 30 cm H_2O

Never exceed 20 cm of H_2O without the doctor's permission or consent!

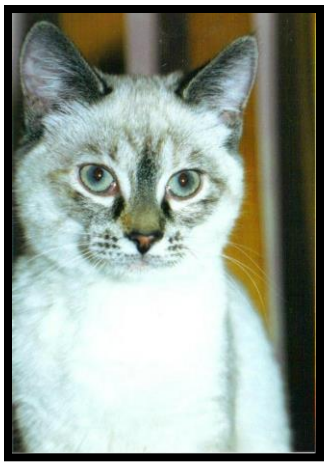
MWPL Pressure Alarm

- When MWPL set-point is exceeded ventilator alarms and terminates inspiratory phase of breathing cycle
- When pressure reaches preset limit, a yellow light will flash and a short tone will sound
- If excessive pressure is not immediately resolved, cycling is paused and alarm sounds continuously

Set Respiratory Rate

Breaths per minute (BPM):

- Dogs: 8 to 14
- Cats: 10 to 14



Inspiratory: Expiratory Ratio

- Inspiratory time is typically 1 to 1.5 seconds in small animals
- I:E ratio minimally should be 1:2 (e.g., 1:3, 1:4, based on respiratory rate)
- The Hallowell 2000 I:E ratio is preset 1:2
  - Set so positive interpleural pressure minimally interferes with venous return and cardiac output
- SurgiVet SAV2500 has adjustable I:E ratio
  - Inspiratory time can be set 0.5 to 3 seconds

Pre-set Volume

- Ensure **Volume** control is at lowest possible settings
  - Lowest V_T deliverable = 20 mls

Set Tidal Volume

Calculate the Tidal Volume:

15 mL/kg (10-20 mL/kg)

- Guideline: ~ ½ the patient's lbs. X 10
- GOAL: 35-45 mmHg (40 mmHg)
- Set volume to minimal settings and adjust prn
  - Estimate tidal volume from bellows housing scale during spontaneous respiration

Set Volume

- Begin with Volume control at lowest possible settings
  - Once patient connected, slowly increase volume based on $ETCO_2$

Volume Alarm

Low Breathing System Pressure

- Alarm activated at end of inspiration if <5 cm H_2O PEEP sensed by APST
- **Alarm sounds like a siren/stolen car alarm and will activate due to:
  - Small breath delivered
  - Patient disconnected
  - Oxygen running low
  - Patient breathing against ventilator

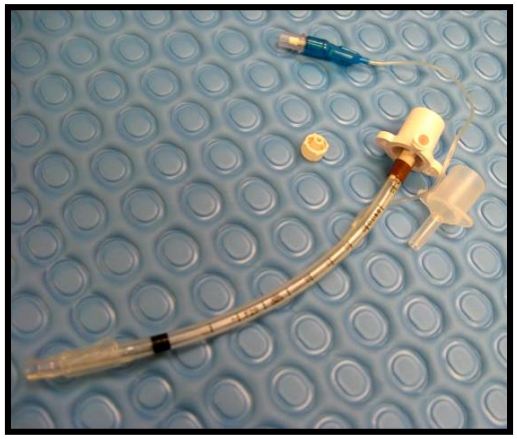
Inspiratory Hold (Insp Hold)

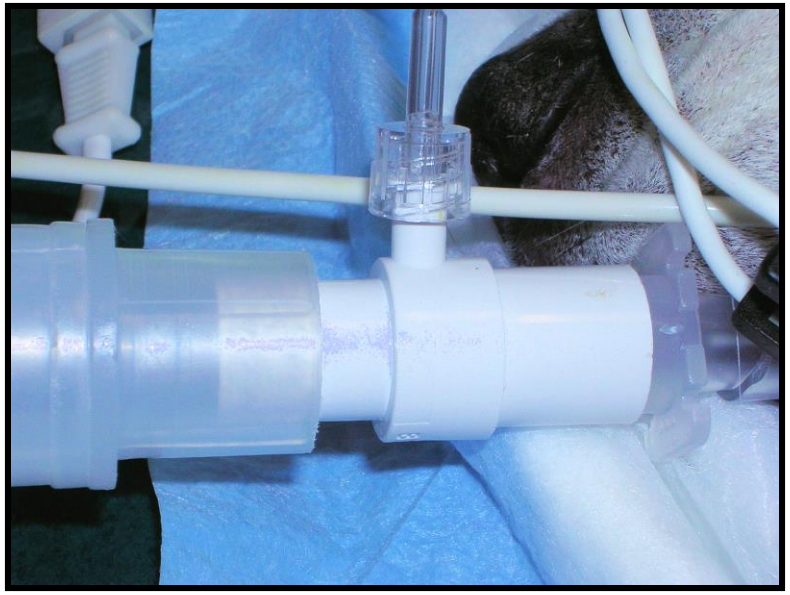
- Pauses breathing cycle
- Holds lungs inflated
  - Breath holding feature will abort once MWPL set point is exceeded

**Turn off or decrease oxygen flow to minimize pressure changes and possible breath abortion

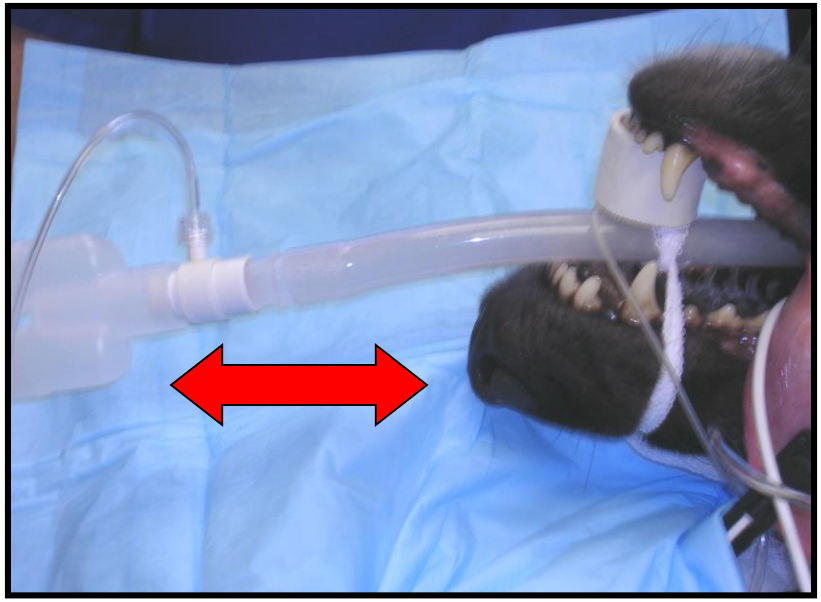
Connect Patient

- Endotracheal tube placement is important!
  - **Shorten ET tubes to eliminate excessive 'dead space'**



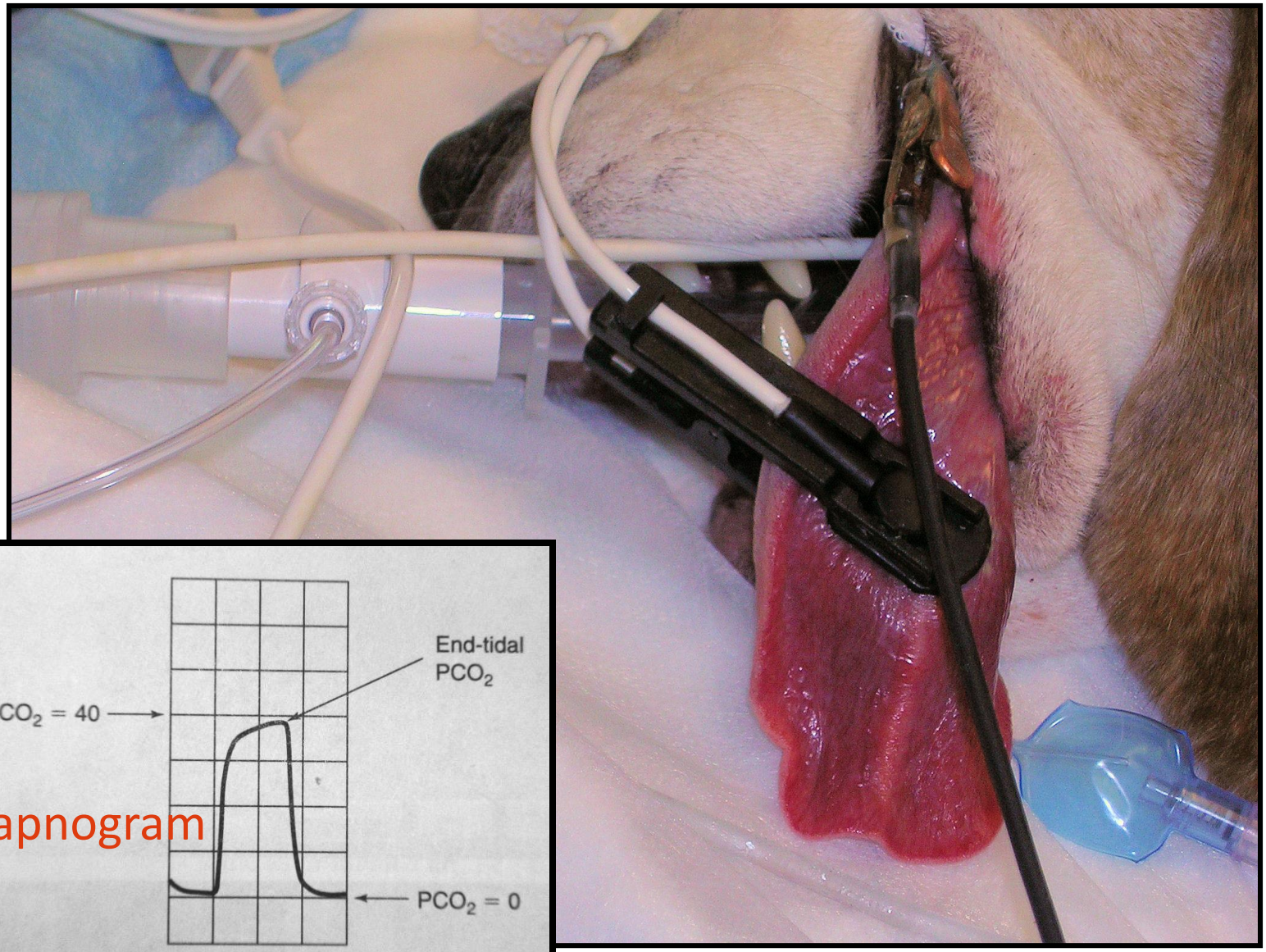


Correct

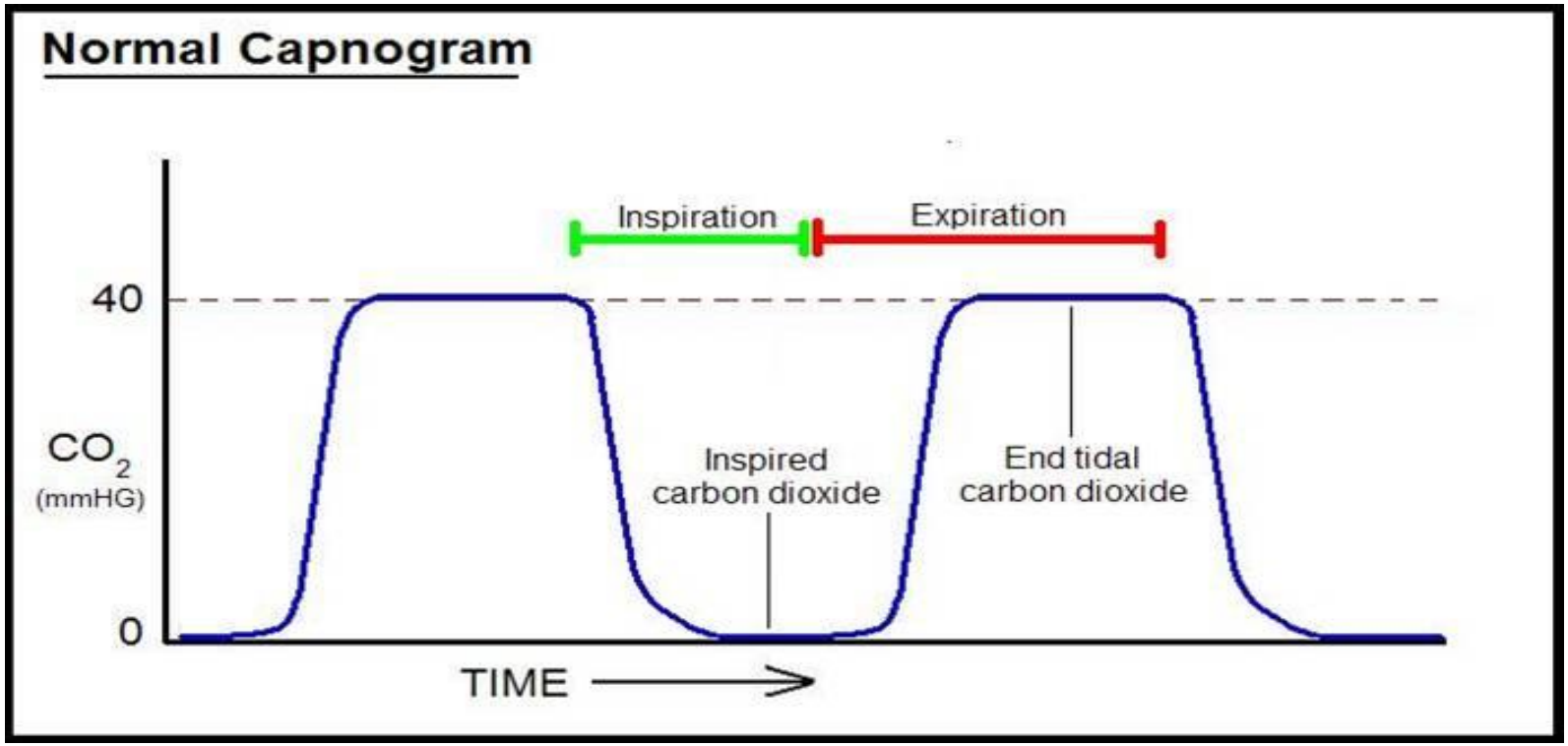


Incorrect

Capnography Proper Set Up



Capnogram Interpretation



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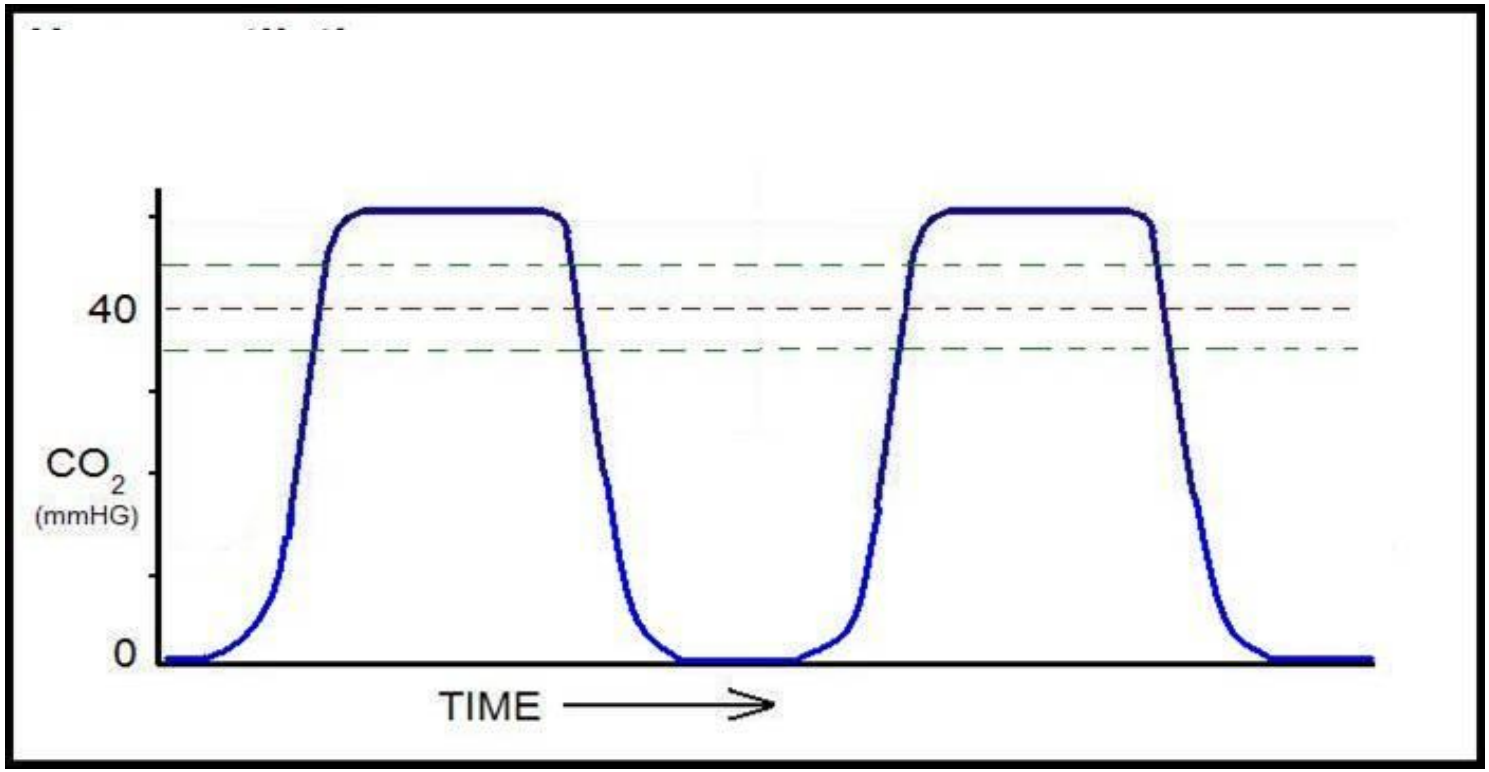

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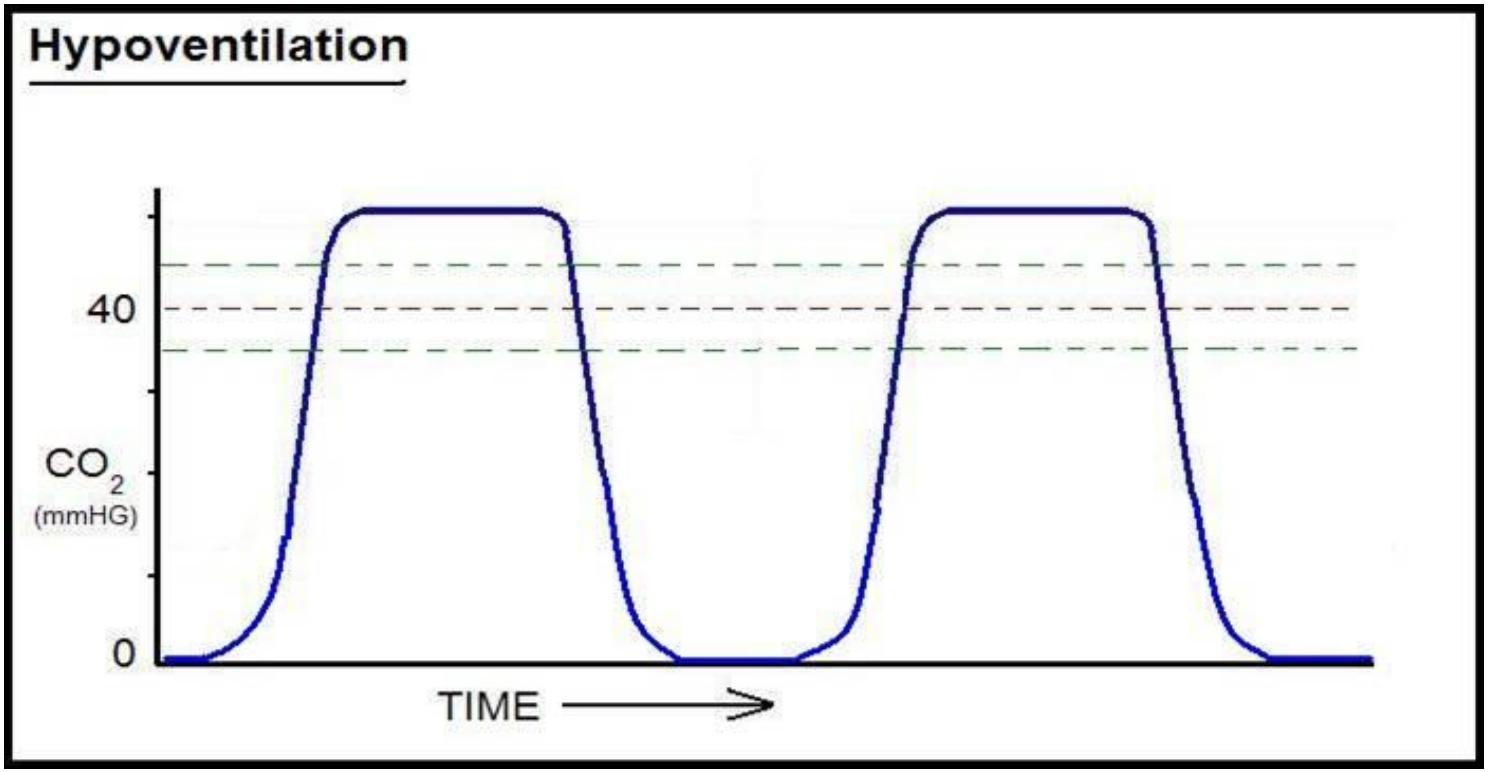

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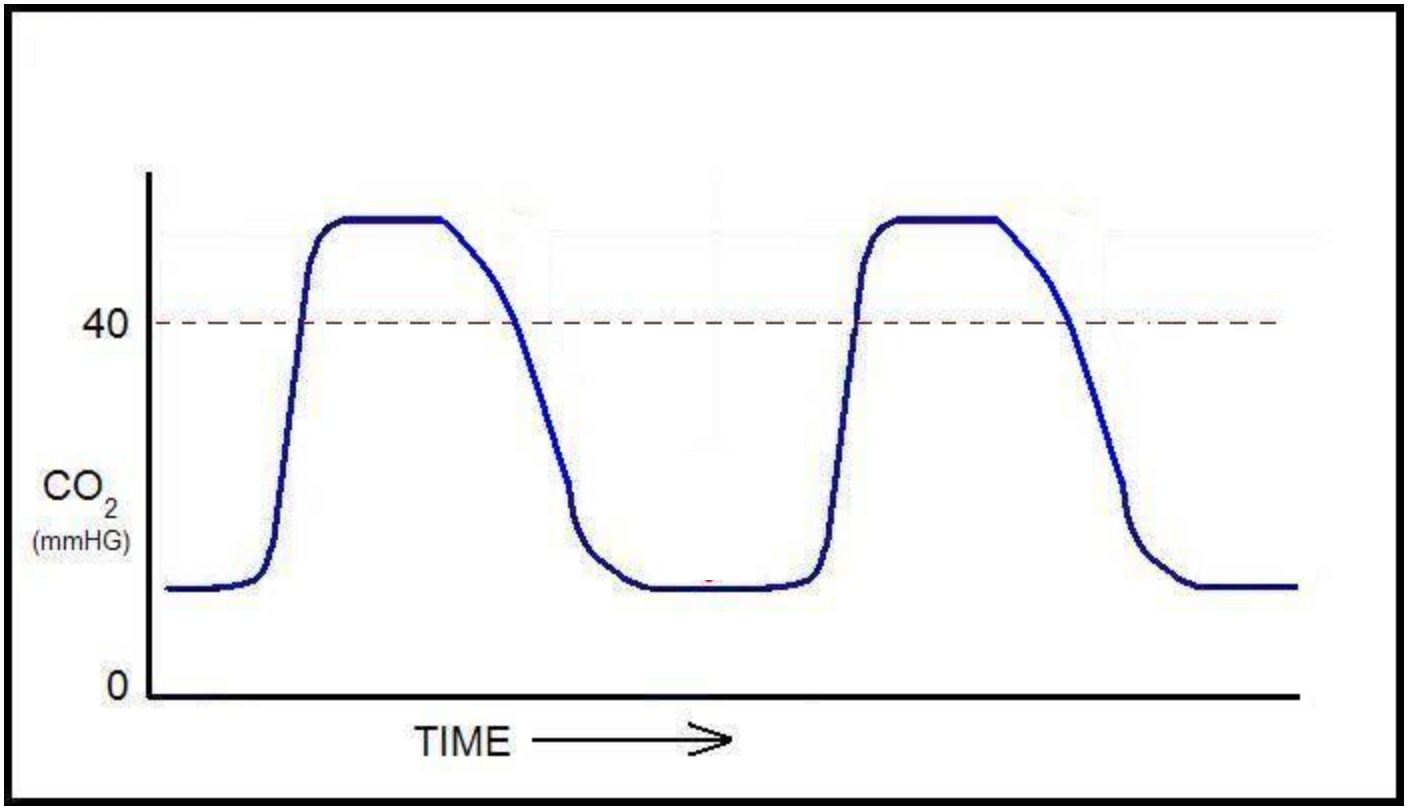

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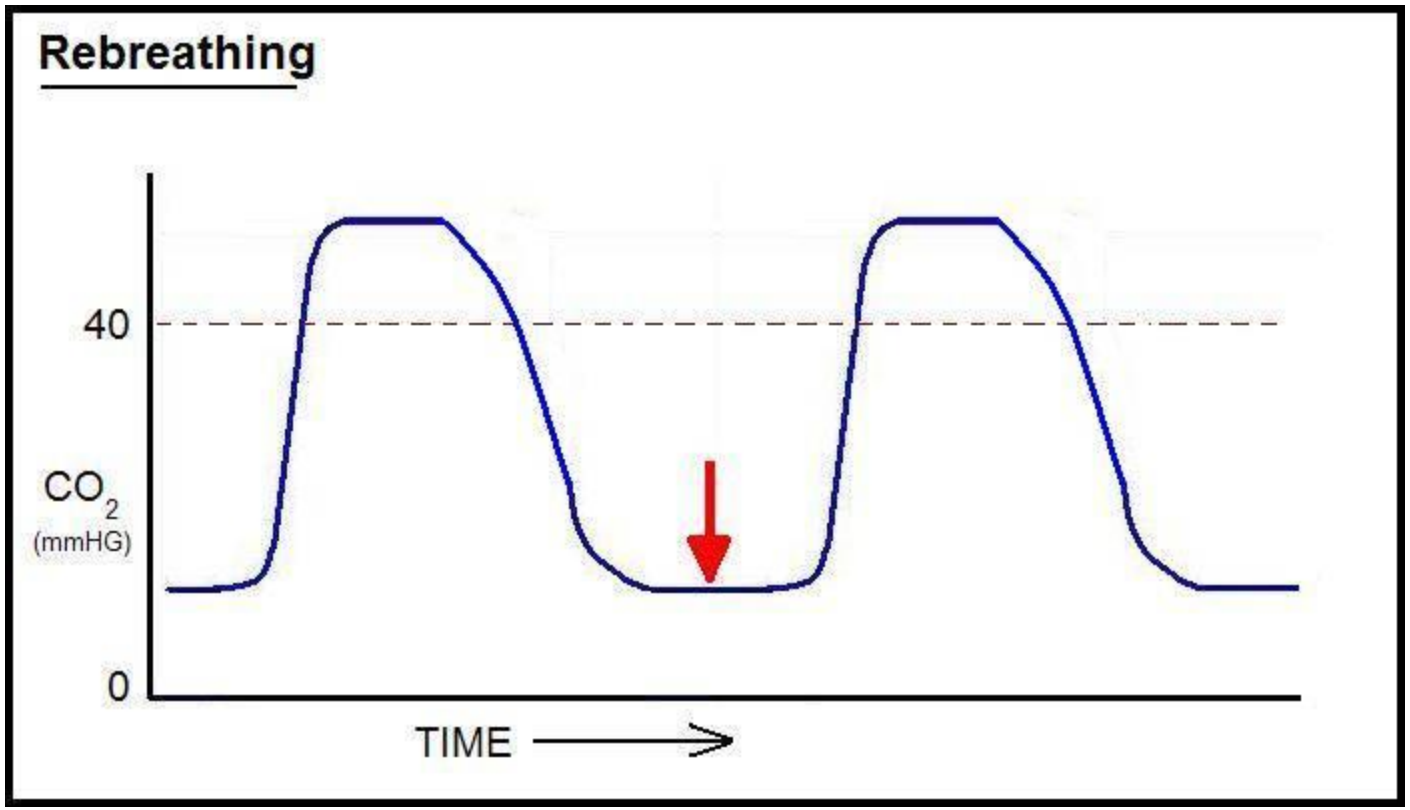

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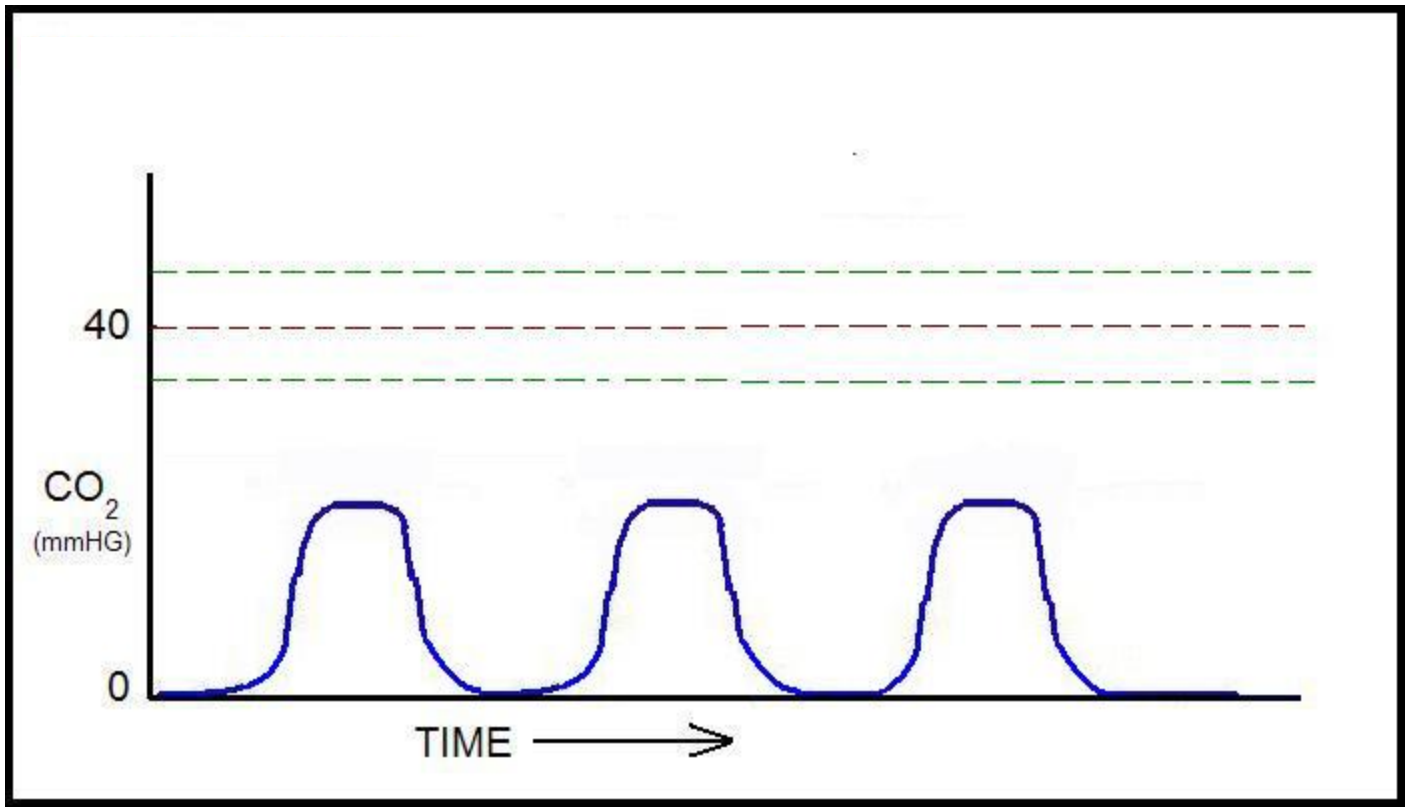

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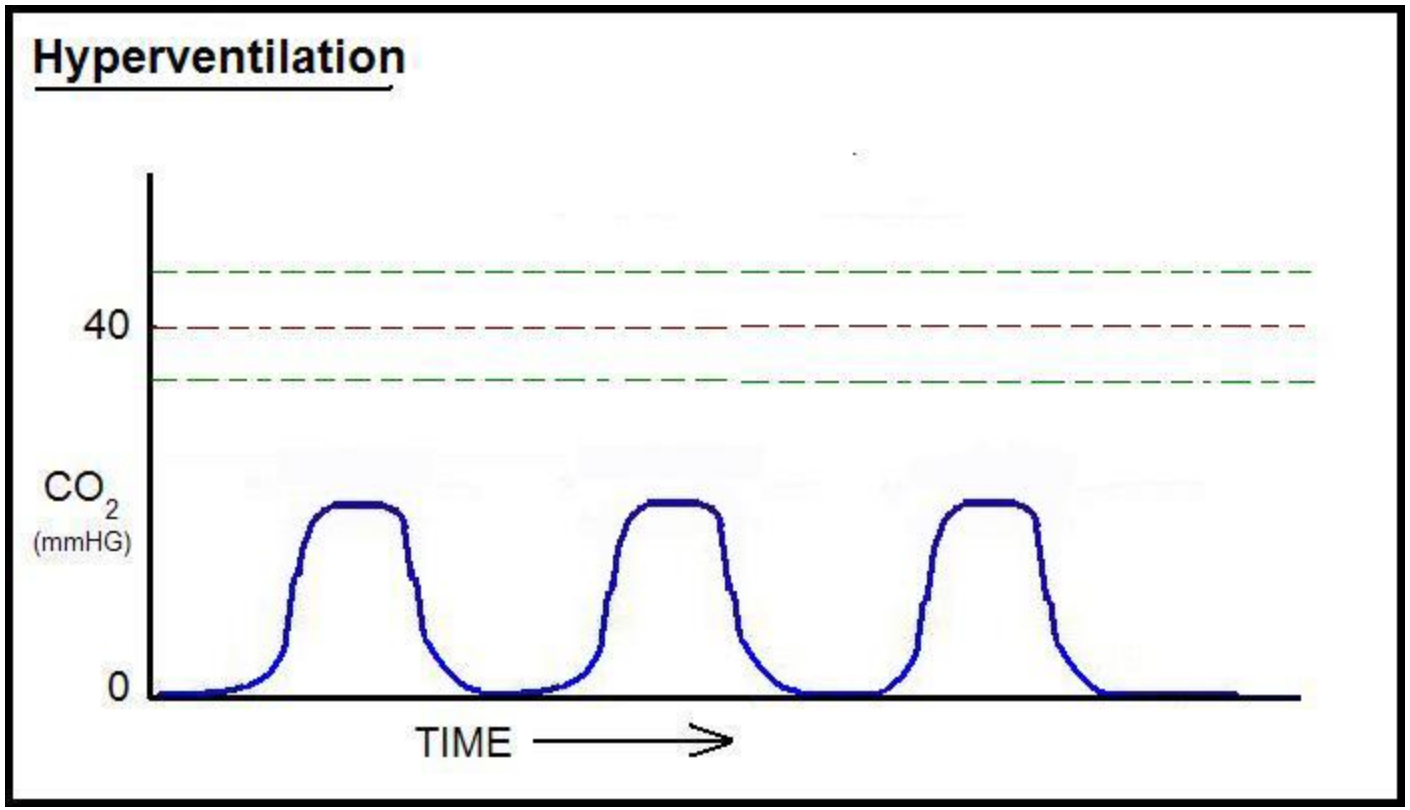

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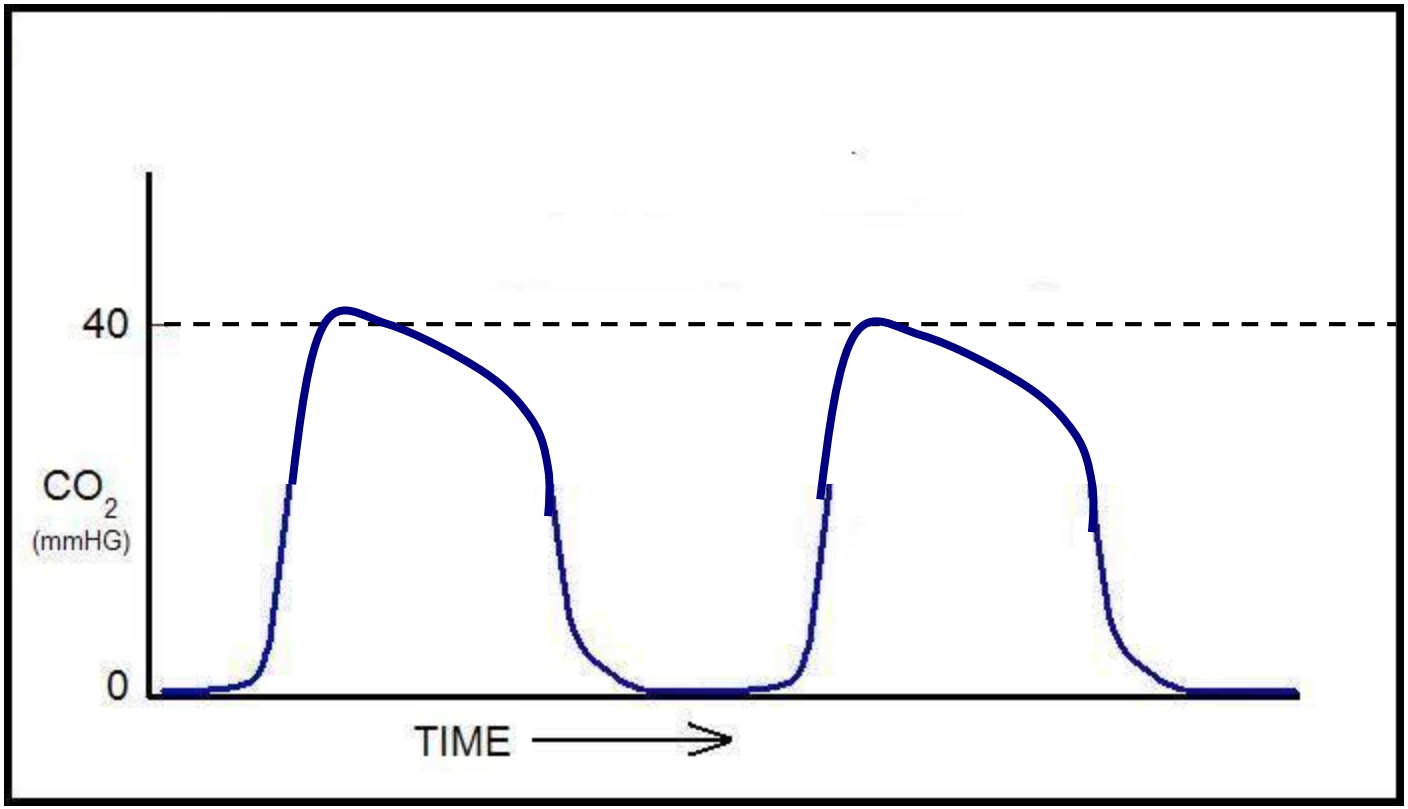

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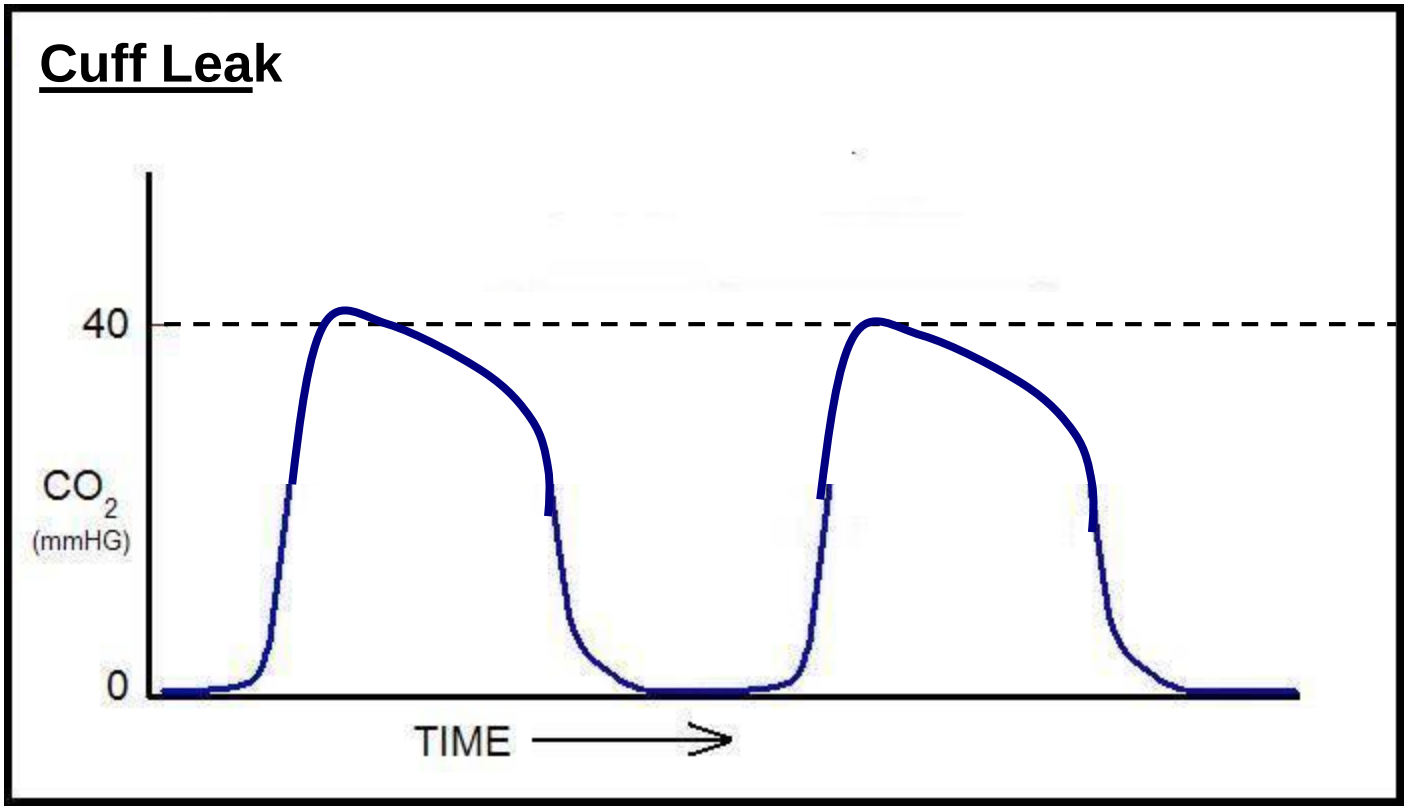

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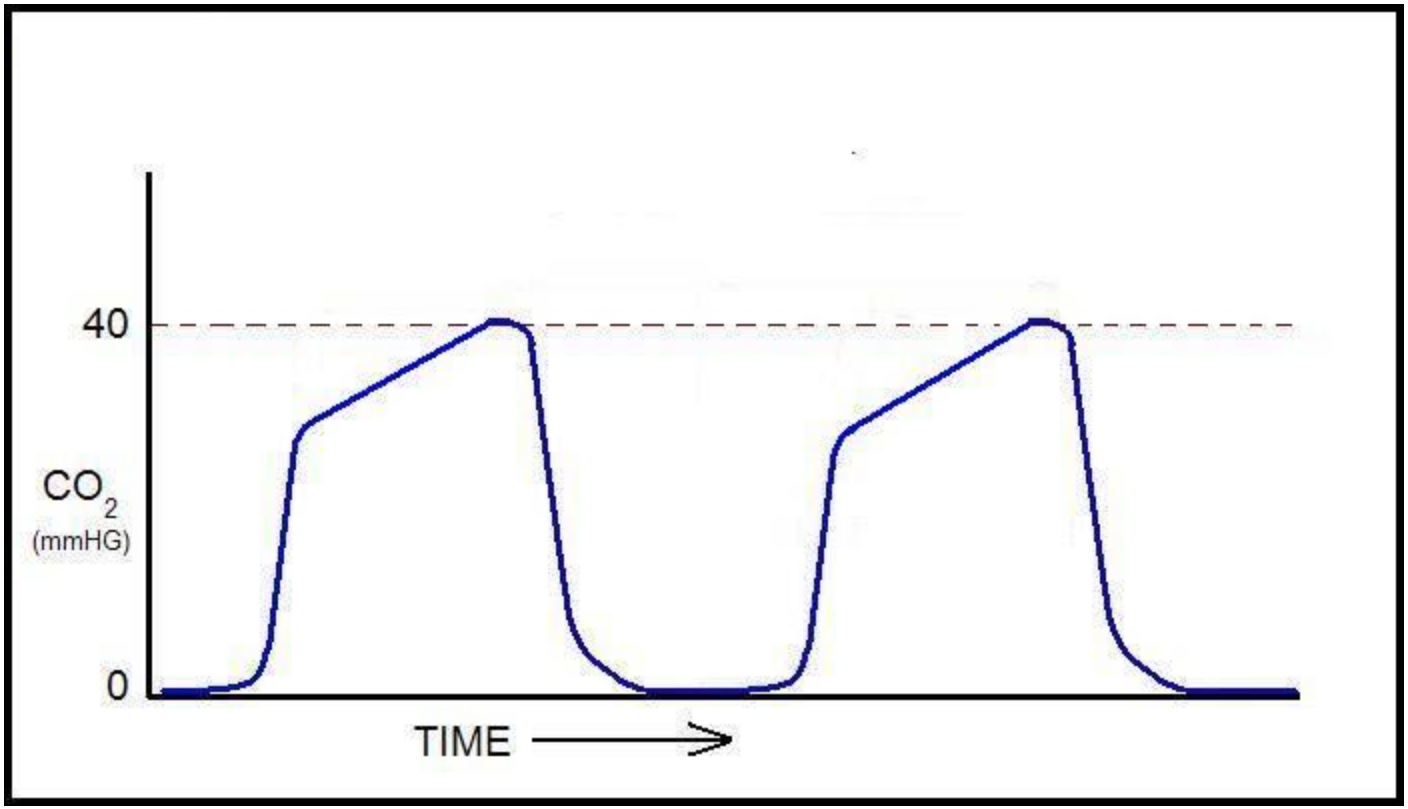

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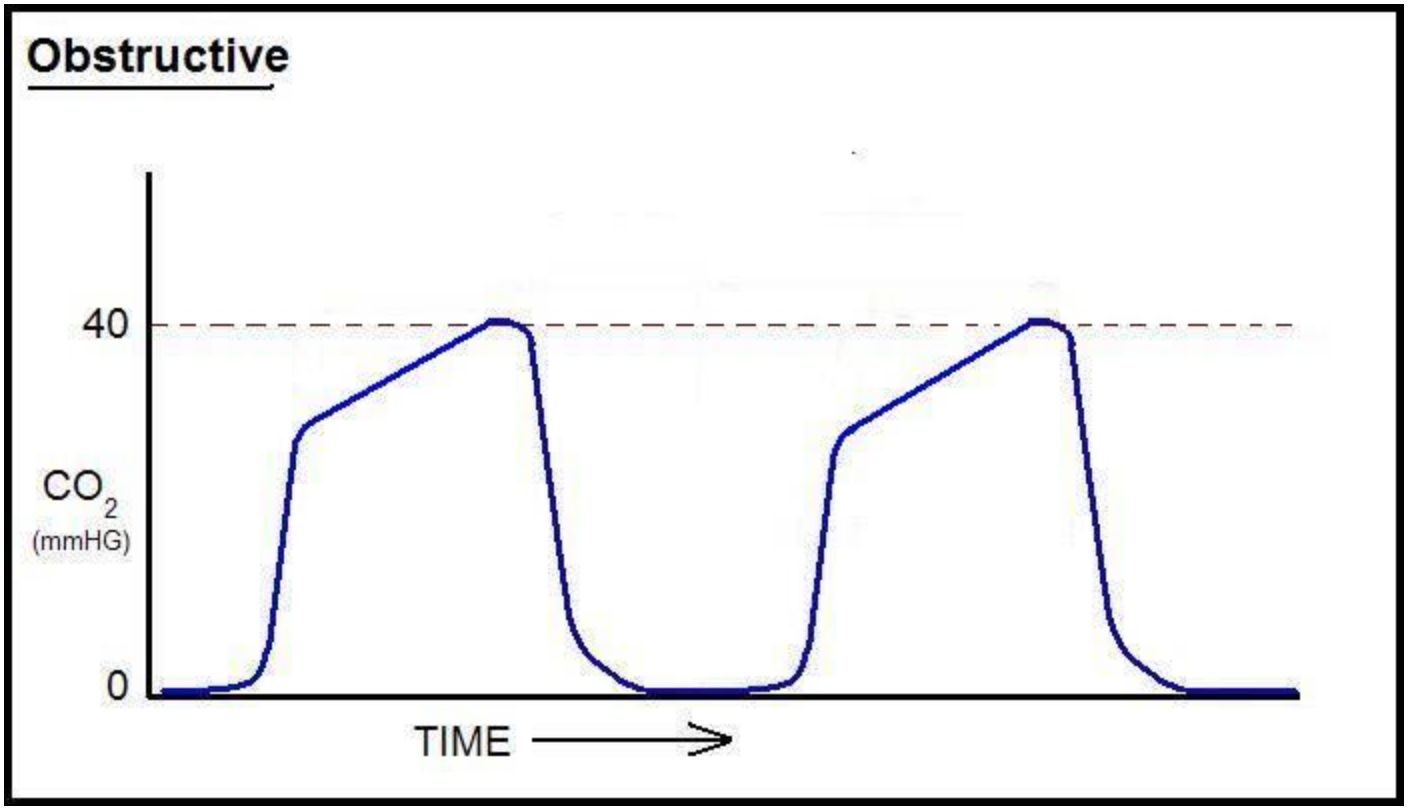

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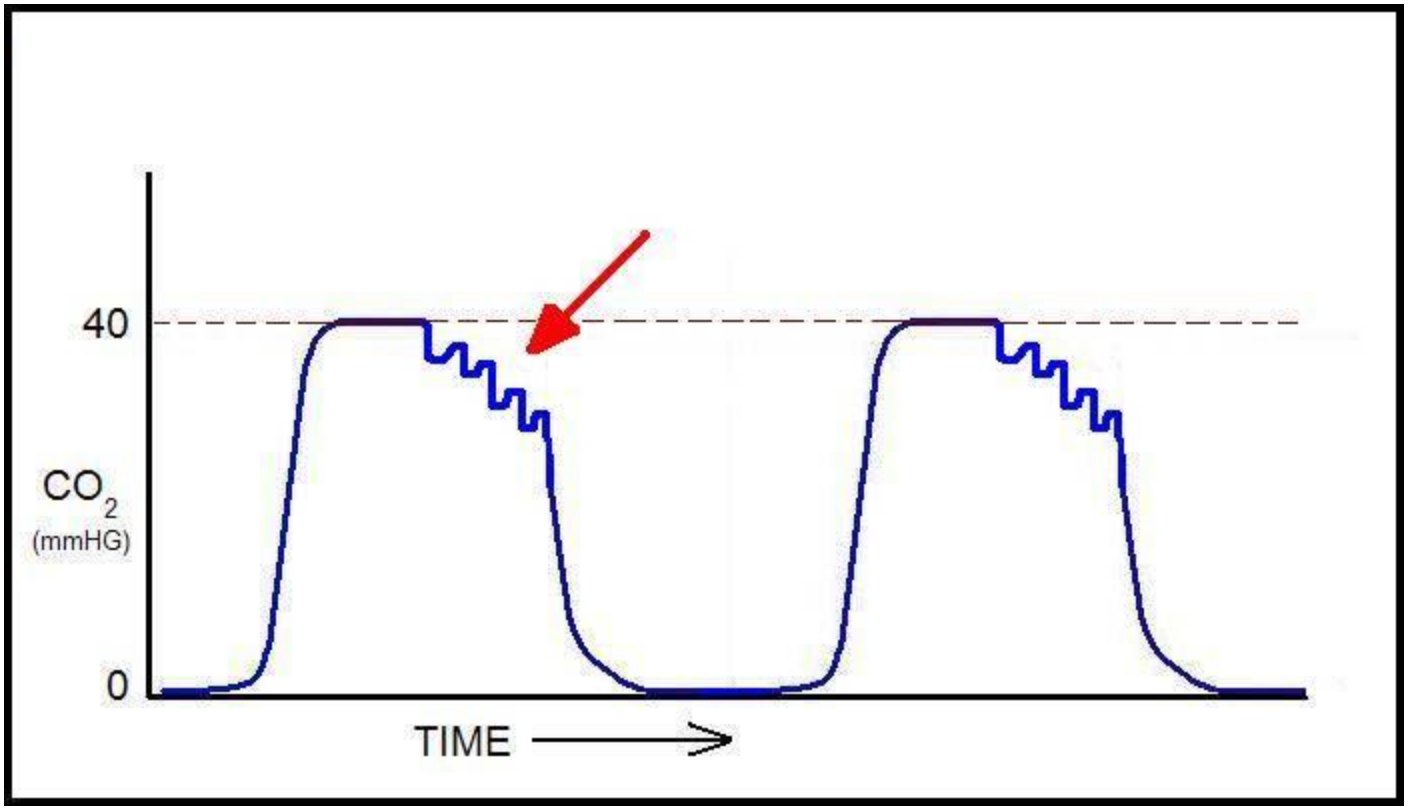

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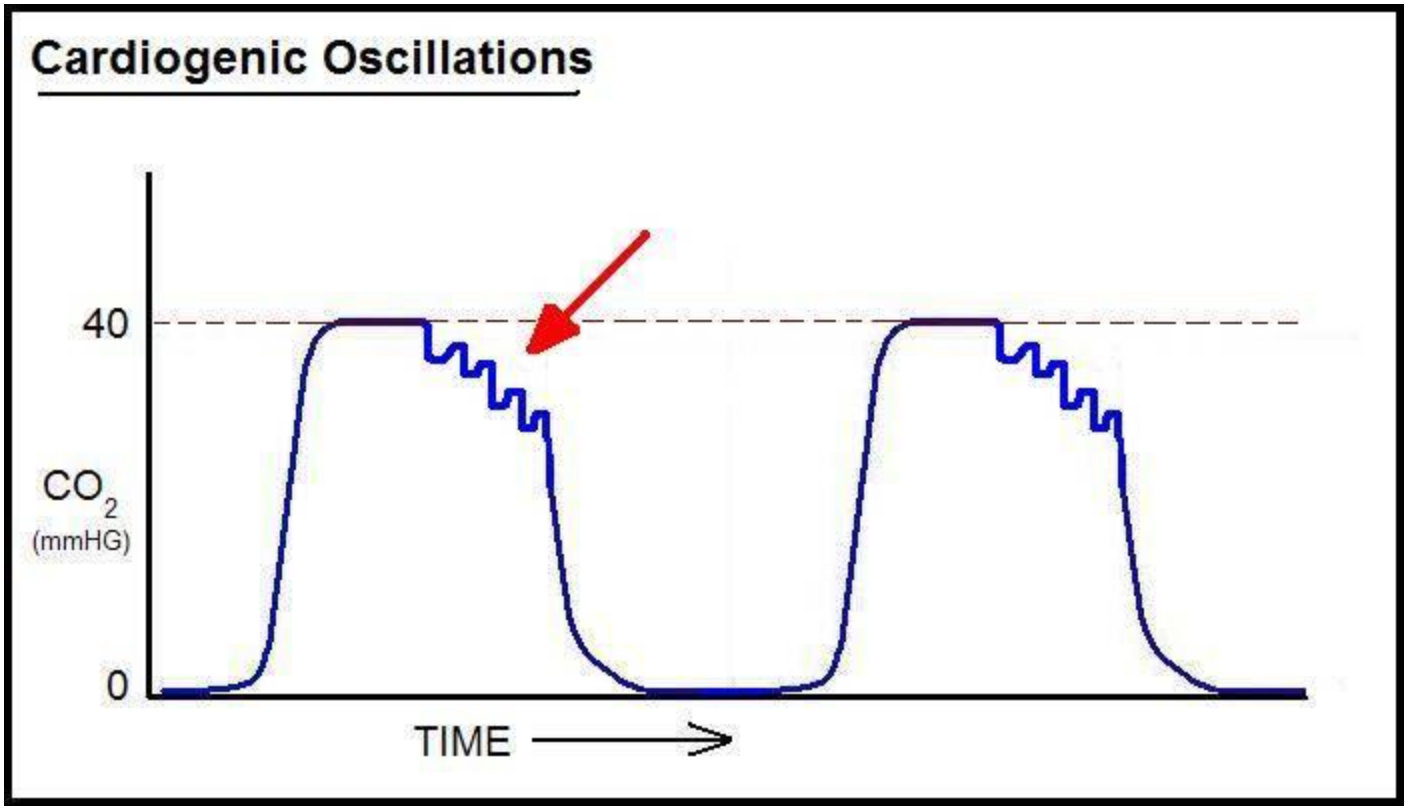

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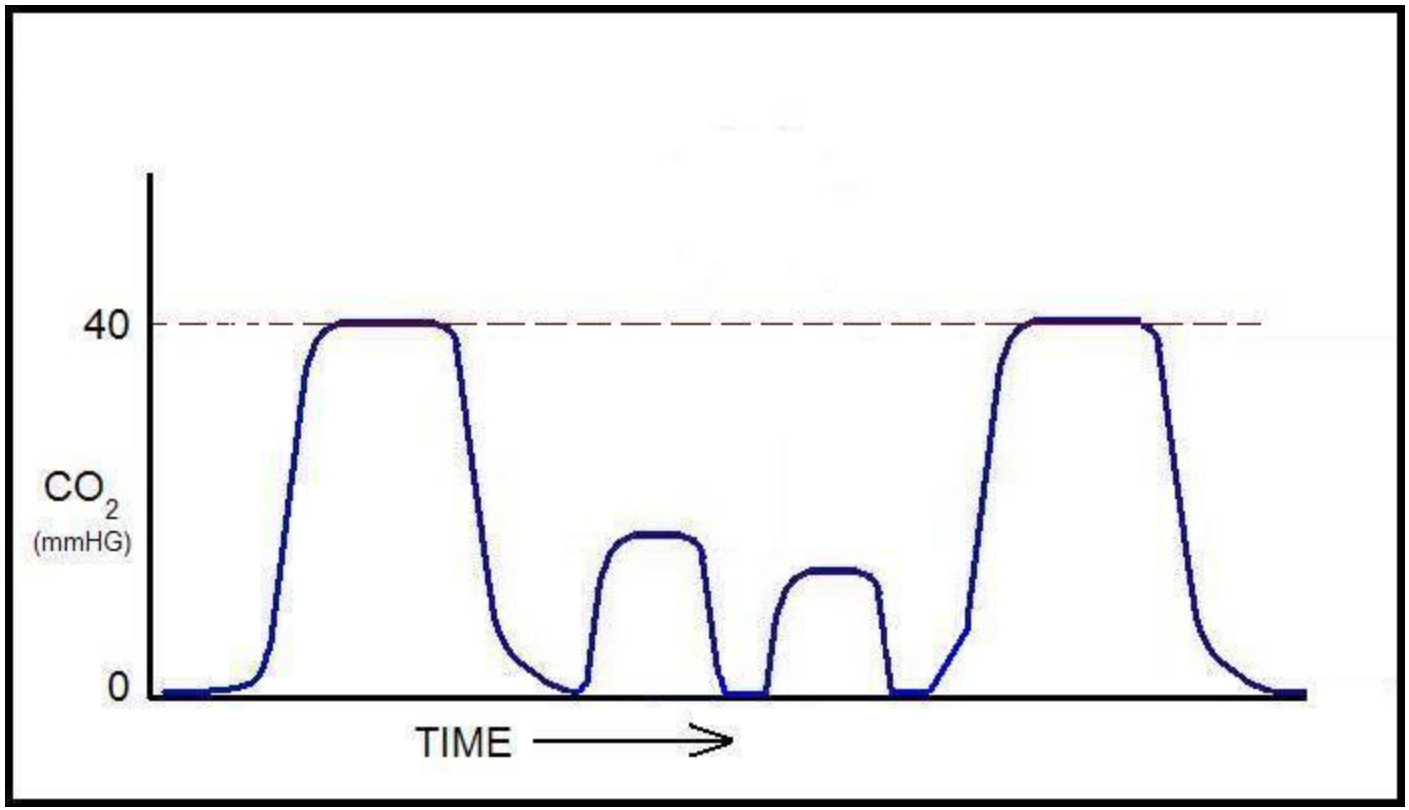
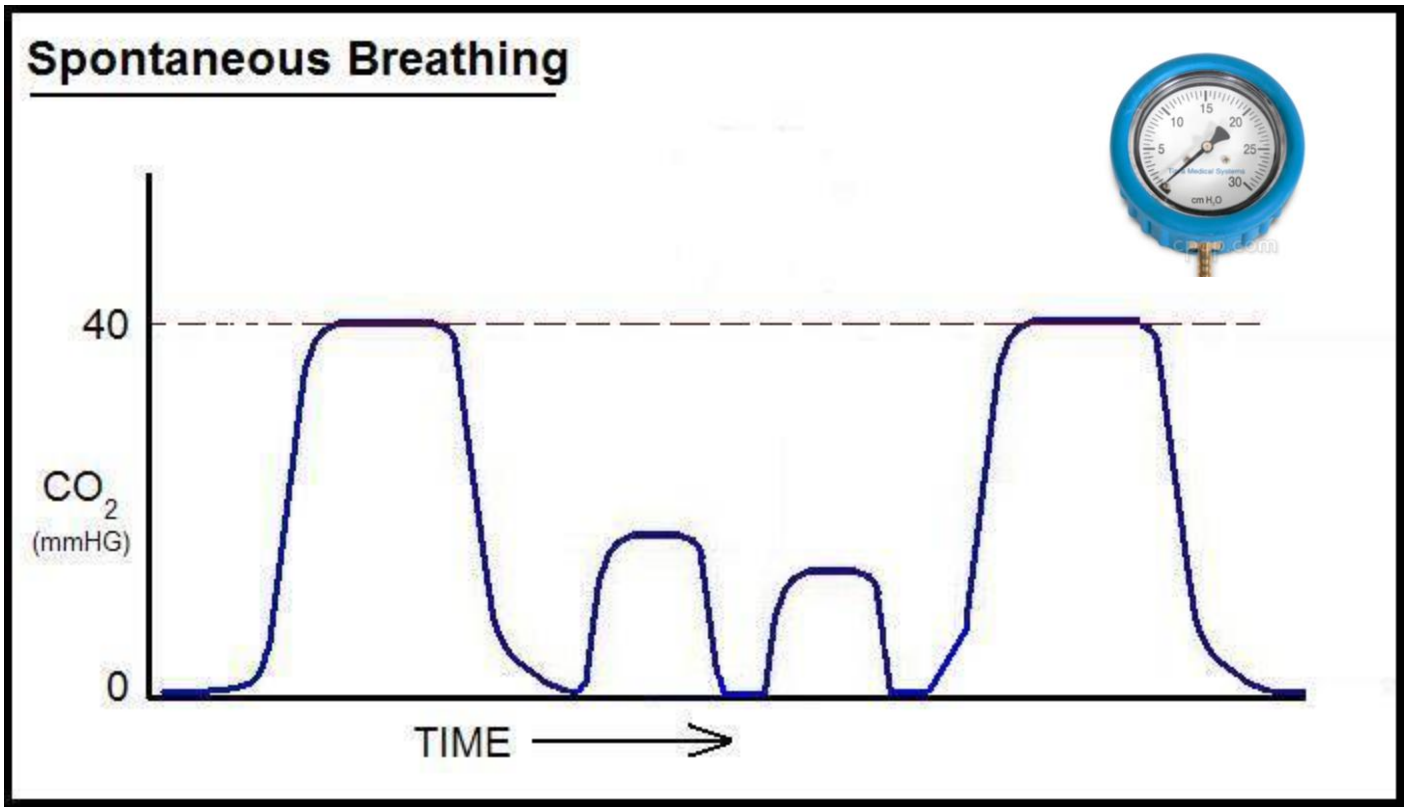


Capnogram Interpretation

- Watch for small movements of pressure manometer needle!



Ventilator Weaning

Respiratory drive regulated via oxygen & carbon dioxide tension in blood

Two methods:

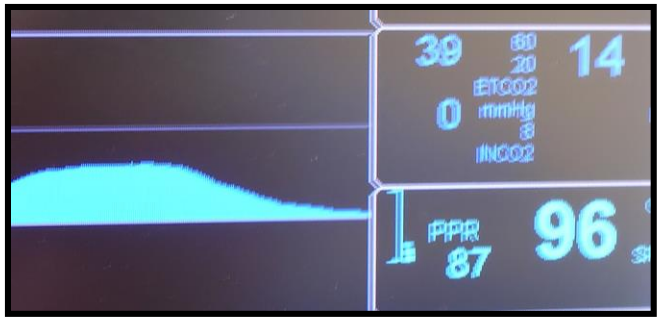
- **'Cold turkey'**
  - Turn ventilator off
  - Wait 1 minute
  - If no spontaneous breath is observed, turn ventilator on for 1 breath
  - Repeat process until spontaneous respirations return

Ventilator Weaning

- **Gradual method**
  - Turn **Rate** down as low as possible (<6 BPM)
  - Turn **Volume** down as low as possible to avoid inciting alarms
  - Observe bellows for return of spontaneous respirations
  - Once patient has resumed spontaneous respiration, turn ventilator off

Troubleshooting Capnography *Equipment Considerations*

- Malfunctioning one-way valves
- Inadequate seal at ET tube cuff
- Inadequate oxygen flow rate
- Moisture within sampling line
- Ineffective (old/wet) CO_2 absorbent
- Esophageal intubation
- Disconnects



Troubleshooting Capnography *Patient Considerations*

- Thoracotomy cases
  - $ETCO_2$ margin of error
    - ABG result ~ 6 mmHg higher than $ETCO_2$
- Metabolic derangement
  - Metabolic acidosis cases may have respiratory alkalosis as pH compensation
- GDV / diaphragmatic hernia cases
  - May require smaller V_T; increase BPM

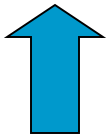
Artificial Ventilation Precautions

- Decrease in arterial blood pressure and cardiac output due to:
  - Average airway pressure >10 mmHg (Ventilator induced)
  - Low circulating blood volume (e.g., anemia, blood loss or dehydration)
  - Impaired sympathetic nervous system activity (e.g., anesthesia, local anesthetics, shock)

Artificial Ventilation Precautions

- Positive pressure in trachea and lungs may be transmitted to thoracic cavity resulting in:
  - Impaired venous return
  - Decreased cardiac output

Ventilator Induced Lung Injury (VILI)

- Barotrauma: pressure-induced lung injury
- Volutrauma: volume-induced lung injury
- Biotrauma: due to sepsis, +/- SIRS, etc.
- Atelectotrauma: 2^{o} atelectasis
- Oxygen Toxicity: >12-16(+) hours
- Long-term =  pneumonia risk

Know Your Equipment!

- Know how to properly use ventilator *before* an emergency arises
  - Improper hook up or use of equipment can result in lung injury! (e.g., barotrauma, volutrauma)
- **Under no circumstances** should O_2 flush on anesthesia machine be used while connected to a patient!
  - Using the flush button during inspiratory phase of breathing cycle can cause severe injury!!!
- **Do not** use alcohol or any other harsh chemical to clean ventilator or bellows
  - Use only a damp cloth


Recommended Reading & Viewing:
www.capnography.com
www.hallowell.com
Document Library
Miscellaneous
Anesthesia Ventilators 101
YouTube
Training: SurgiVet SAV25000 (sic) Ventilator