Respiratory Mechanics, Mechanical Ventilation and Blood Gas Management

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OUTLINE / OBJECTIVES

Part 1 – Respiratory Mechanics

- **Understand how the cardio-respiratory-neural-[Doctor] unit regulates O2 and CO2**

Part 2 – Mechanical Ventilation Modes and Other Methods of Respiratory Support

Part 3 – Blood Gas Management

- **Understand how to interpret the basic components of a blood gas**
- **Review strategies to correct metabolic acid / base disturbances**
- **"Workshop" blood gases and ventilator changes**

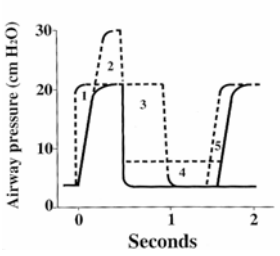
Part 1- Respiratory Mechanics

- **Both O2 and CO2, require regulation and this is accomplished by the combined cardio-respiratory-neural unit in the breathing patient and by cardio-respiratory-neural-Doctor unit in the intubated patient**
- **While there is definite overlap, it is useful to conceptualize control of oxygenation (PaO2) and ventilation (PCO2) separately**

OXYGENATION

- **Dependent on O_2 delivery…**
  - To the alveoli
    - F_I0_2 – higher fraction/ available O_2
    - MAP – recruit alveoli for gas exchange
  - To the tissues
    - Cardiac output – support blood pressure
    - Oxygen carrying capacity (I.e. Hb since O_2 bound to Hb >>> dissolved O2) => consider PRBC if Hct <35 and on vent/O_2

How does one manipulate Mean Airway Pressure?



1. Higher Flow
2. PIP*
3. Longer Ti
4. PEEP*
5. Shorter Te

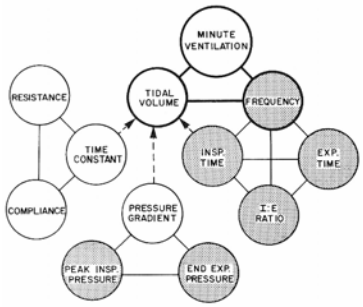
* Remember since generally Te>Ti, MAP is more influenced by changes in PEEP compared to PIP

$$\bar{P}aw = K(PIP - PEEP)[T_I/(T_I + T_E)] + PEEP$$

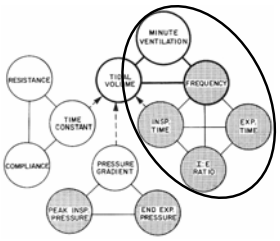
VENTILATION

Minute Ventilation Determines $PaCO_2$

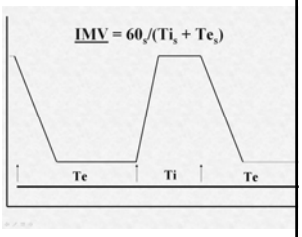
$\dot{V} = TV * RR$



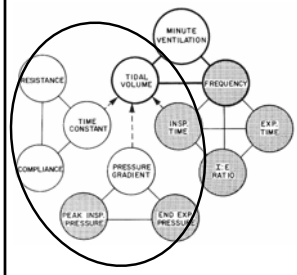
RR = IMV



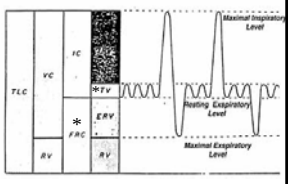
What determines IMV?

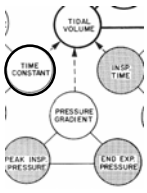


What determines TV?

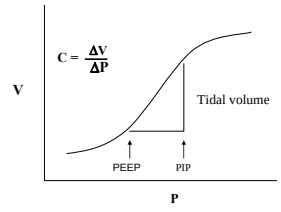


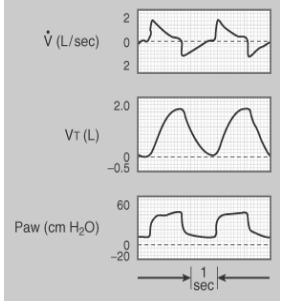
FRC also influences TV

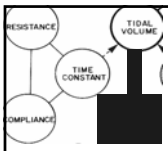




In a simple world think… "Area under the curve"





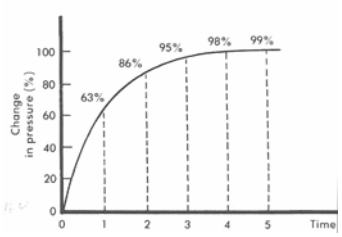


Time constant is a product of R & C

What about Resistance?

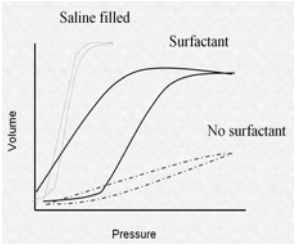
It's all about the time it takes to get there

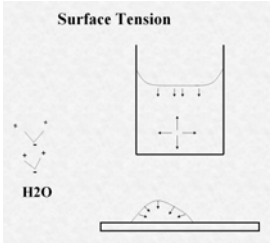
$R = cmH_2Os^1L^{-1}$



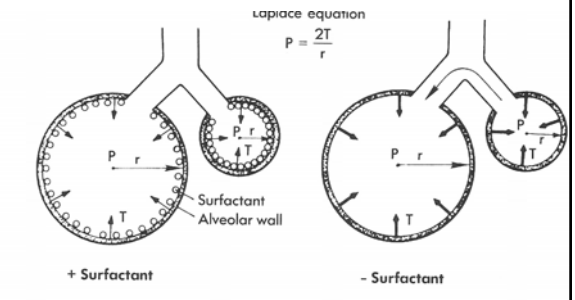
TC = R X C [cmH_2O s L^{-1}] X [L cmH_2O^{-1}]

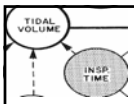
Surfactant (or lack of it) affects Lung Compliance



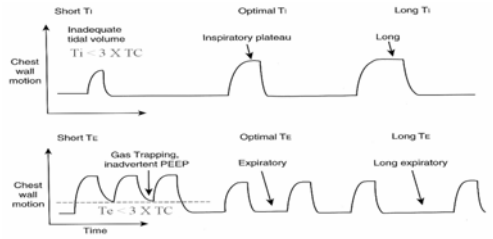


Surfactant: surface tension reduction and alveolar stabilization





The Balance between Ti and Te



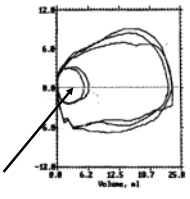
You need enough Ti to achieve adequate TV but also enough Te to "blow off" CO2/ avoid air trapping

Part 2 - Mechanical Ventilation and Other Modes of Respiratory Support

- **Conventional Mechanical Ventilator**
  - **SIMV- Pressure control (+/- PS)**
  - **AC**
  - **Volume ventilation (e.g. Volume-guarantee, PRVC) we don't use commonly so not discussed here**
- **High Frequency Ventilation**
- **CPAP**
- **Vapotherm**
- **Nasal Cannula**

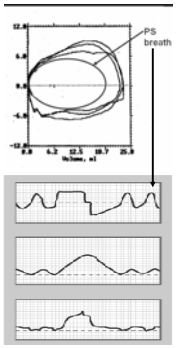
Synchronized Intermittent Mandatory Ventilation (SIMV)

- **Mechanical breaths are *synchronized* to trigger the ventilator with the onset of a spontaneous patient breath (prevents "stacking" of pressures)**
- **If baby's respirations are absent or inadequate, a fixed back-up ventilatory rate is provided (~IMV)**
- **Assisted breaths are triggered by patient only during "assist windows" – breaths at other times are supported by baseline pressure (PEEP)**
- **Valuable mode as a rate-weaning strategy**



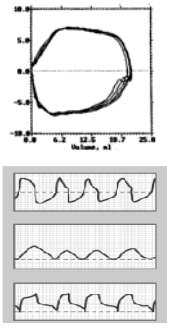
Pressure Support Ventilation (SIMV+PS)

- In SIMV + PS mode, every attempt of the infant to breathe triggers a ventilator breath
- The SIMV set rate guarantees PIP at the prescribed rate and t_I, even if the infant is completely apneic
- All infant initiated breaths <u>not</u> receiving PIP are supplemented with a PS + PEEP during the infant's effort
- PS + PEEP is usually <u>less than</u> PIP
- PS + PEEP helps overcome ET tube and ventilator resistance



Assist Control (AC)

- Method of ventilation in which breaths are either triggered by the patient (assisted), or are ventilator initiated (controlled)
- All breaths are identical, since a patient triggered breath, no matter how frequent, produces a full ventilator breath
- If breathing is absent, the ventilator delivers all breaths at a pre-set rate
- If patient is breathing at a rate over the back up rate, cannot use a rate weaning strategy



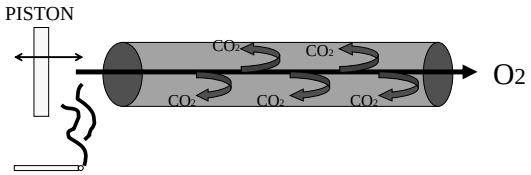
High Frequency Ventilation

- There is very little evidence to support early use of HFV, and much evidence against it (PVL, IVH?)
- Indicated when continued respiratory failure on CMV (i.e. rescue therapy)
  - VLBW on PIP>25
  - F_IO_2>0.7
- Also useful in early PIE/ airleak

HFV

- **"Gentle ventilation"- works by recruiting alveoli (can achieve higher MAP with lower PIP, allows gas exchange at lower lung volumes)**
- **Allows maintenance and consistency of lung volume throughout the respiratory cycle, through appropriate use of end distending pressure**
- **More even distribution of gas volume in the lung**
- **Improves V/Q matching**

HFV- how does it work?



Think of blowing smoke into the end of a pipe…
Pushing air column (O2) into the lungs and CO2 diffuses out

HFOV- The Oscillator

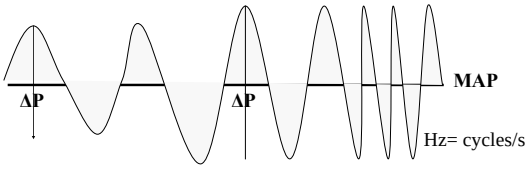
HFOV - MAP

- **Controls oxygenation**
- **Usually start at 1-2 cm H20 above MAP on CMV**
- **Follow inflation on CXR**
- **Wean FiO2- once <60%, consider weaning MAP**
- **For airleaks- may wean MAP first**

HFOV – Delta P and Hz

- **Controls CO_2 elimination**
- **Titrate ΔP to "jiggle" – usually 25-30**
- **Hz- usually 10-12 (15 for small babies)**
- **Increase MV/TV (i.e. decrease pCO_2) by increasing ΔP or decreasing Hz**

"area under the curve"



HFOV - weaning

- **Careful of the "critical threshold" concept:**
  - **Can wean MAP to the point of lung collapse- following inflation on CXR is helpful**
  - **Can wean ΔP to the point of loss of "jiggle"- then you're no longer oscillating = baby + ET + loud box**
- **Can extubate from HFOV**
- **May consider change to CMV prior to extubation, especially if unsure patient will have respiratory drive (e.g. preemies with apnea, other babies with risk for central apnea)**

Other Respiratory Support Strategies

- NCPAP (PEEP 5-8 cm H20)
  - Prevents alveolar collapse, splints airway
  - Stimulates surfactant secretion and lung growth
  - Concerns: nares/ septum breakdown (positioning/ sizing of prongs) and "CPAP belly"/ NEC risk (OG/NG)
- Vapotherm (2-8 LPM)
  - delivers molecular vapor with nearly 100% relative humidity at body temperature
  - allowing high-flows (up tp 8L) to be tolerated
  - Concerns: ? How much PEEP is really being delivered
- Nasal Cannula (1-2 LPM)- O2 blended w/ humidified air
  - Low flow (1/8 – ½ L), 100% FiO2 for home

Part 3 – Blood Gas Management

pH/pCO2/pO2/HCO3/ BE

Decisions to make:

1. Acidosis vs alkalosis – Look at your pH!
2. Metabolic (HCO3, BE) vs respiratory derangements (PCO2) vs mixed
3. What is "normal" or desired for your baby (i.e. the Respiratory Care Plan)

The Respiratory Care Plan

Depends on the type of baby!!!

Typical new preemie w/ RDS:

pH: 7.25-7.4 (allowing for acidosis)

pCO_2: 45-55 (some permissive hypercapnia)

pO_2: 50-70 (SaO2 88-93%) (avoid O2 toxicity)

FT w/ PPHN

pH: 7.35-7.45 (mild alkalosis)

pCO_2: 35-45 (mild hyperventilation)

Respiratory Care Plan

- Should be written each day
- May change from day to day – should be discussed on rounds (e.g. PPHN babies progressing from acute/ labile phase and ex-preemies with evolving BPD/ CO_2 retention may have changing parameters)
- Should be specific to communicate goals/ weaning strategies to RNs/ RTs
  - e.g. "wean F_IO_2 by __% for SaO_2 (vs PO_2)" or "wean PIP (vs IMV) for PCO_2 in care plan" etc)

Metabolic Acidosis/ Alkalosis

- "To buffer or not to buffer…"
- Remember to consider what is *physiologic* for your patient!
  - Preemies have lots of reasons for metabolic acidosis- anemia, dehydration, immature renal function etc.
  - CLD babies will have *compensatory* metabolic alkalosis for CO_2 retention.
- How to decide what is physiologic?
  - A clue is the pH. If it's normal/ acceptable for your patient you probably don't need the buffer.
- Treat the underlying cause, not the numbers.
  - If a baby has worsening acidosis, don't just repeat the buffer bandaid. Think about sepsis, NEC, anemia, hypovolemia, etc.

Metabolic Acidosis

- Treat if pH out of care plan with significant base deficit
- $NaHCO_3$ (1-2 meq/kg):
  - will raise pCO2 so careful with mixed acidosis
  - gives Na load so careful in hypernatremia
- THAM (1-2 meq/kg): larger volume
- Why not buffer everyone?
  - Temporizing measure unless the underlying

Metabolic Alkalosis

- Rare as a primary disturbance so consider if this is normal physiologic compensation!

If decision made to treat:

- Hypochloremia maintains the alkalotic state – goal to supplement to Cl > 100
  - Prefer NaCl or KCl if serum Na / K low
  - Can also use NH_4Cl
- Acetazolamide (Diamox)- carbonic anhydrase inhibitor with diuretic effect leading to renal NH_3 loss

CASES

Case #1

- A 1200 gm baby with RDS is stable on SIMV 40, PIP 18, PEEP 5 + PS 5 and 75% F_IO_2 his bedside SpO_2 monitor reads 100%
- A blood gas has pH 7.40, $PaCO_2$ 45, and PaO_2 175.
- Which of his settings is most toxic?
- What change(s) do you want to make?
- When do you want your next blood gas?

An answer

- F_IO_2 > 0.7 is toxic
- Lower the F_IO_2 by no more than 10% of 70%, so let's say -5% to 0.7 fraction.
- Get another gas in 60 minutes, or re-assess SpO_2 and wean F_IO_2 again.

Case #1 revisited

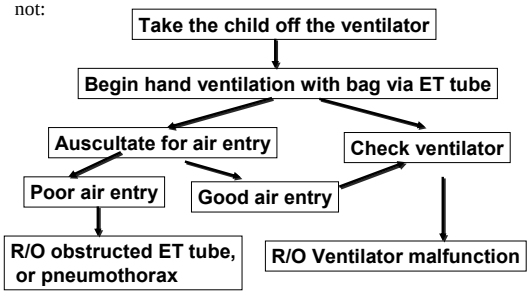
- That nice little premie suddenly deteriorates, his SpO_2 monitor reads 40% saturation, and his skin looks gray.
- The repeat blood gas at 30 minutes is pH 7.10, $PaCO_2$ 95, and PaO_2 17.
- What are your first 2 thoughts (remember your ABC's, A & B should be your first 2 thoughts)?
- What do you do?

An answer

- Brilliant! You took the baby off the ventilator to hand bag, you think the ET tube is in good position, but breath sounds on the right are diminished
- Brilliant again! You transilluminate both sides and the right side lights up like a paper lantern
- You needle the chest for 40 mL air, order an X ray, return the baby to his previous ventilator settings, and repeat a blood gas in 30 minutes.
- The night is yet young.

Sudden Deterioration – What To Do …
The answer isn't always in the ventilator settings…
GO TO THE BEDSIDE!!!

Is there chest rise? (on CMV) Is the baby jiggling? (on HFOV) If not:



Case #2

- **A 5000 gm lug of a meconium aspiration baby is receiving ventilation at SIMV 50, PIP 25, PEEP 6 + PS 10, and is on an F_IO_2 of 1.00, his SpO_2 is labile between 88-95%**
- **A blood gas has pH 7.45, $PaCO_2$ 35, and PaO_2 75.**
- **Which of his settings is most toxic?**
- **What change(s) do you want to make?**
- **When do you want your next blood gas?**

An answer

- **This baby is likely to have labile PPHN, and 100% oxygen is his most toxic setting**
- **Respiratory alkalosis is his best friend**
- **So is normoxemia**
- **Do nothing**
- **Get blood gases every 2 hours or sooner**
- **Kiss the call room good night!**
- **Order a chest film for the morning**

Case #3

- A 251 day old chronic lung premature is stuck on ventilator settings of SIMV 20, PIP 17, PEEP 6 + PS 6, and is on an F_IO_2 of 0.38, his SpO_2 is labile between 88-92%
- A morning blood gas has pH 7.25, $PaCO_2$ 55, and PaO_2 55.
- Which of his settings is most toxic?
- What change(s) do you want to make?
- When do you want your next blood gas?

An answer

- Probably his most toxic setting is PIP contributing to inexorable barotrauma.
- Any change you make is probably OK, don't move more than 10% on any one setting at a time.
- You could drop both his PIP and PEEP by 1 cm H_2O reasoning that your tidal volume would remain about the same.
- Tomorrow's ABG is not too long to wean a chronic lung baby again.

Case #4

- A 1 day old 1000g preemie with RDS is stable on the vent with settings PIP 15, PEEP 5, IMV 30, FiO2 40%.
- The RT brings you the respiratory sheet with an ABG 7.24/56/100/-5 because it is "out of care plan"
- She asks "Do you want to treat this -5 or do you want me to go up on the vent?"
- What is your response?

An Answer

- Ask her to wean the F_IO_2.
- Remember you don't always have to "do something"
- Don't forget to assess the baby's hydration status, hematocrit, blood pressure etc, especially with persistent or worsening acidosis.

Our Neonatal Division Discussing Ventilation Strategies, THE END