Lung Wit and Wisdom

Understanding Oxygenation and Ventilation in the Neonate

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Objectives

- To review acid base balance and ABG interpretation in the neonatal population
- To review airway management and mechanical ventilation in the NICU
- To discuss uses for non-invasive ventilation
- To discuss current trends that decrease the incidence of Chronic Lung Disease

Section 1 – In the NICU

ABG's and the Neonate

Acid Base Balance

- Understanding the Physiology
- Acidosis vs. Alkalosis
- Blood Gas Interpretation

Physiology

- pH is directly related to H+ concentration in body fluids
- High H+ corresponds to a low pH which equals acidosis
- Low H+ corresponds to a high pH which equals alkalosis
- Regulation of H+ occurs through-
  - Buffers (HCO_3, plasma proteins, Hgb)
  - Excretion
  - Compensation

Physiology

- "The relationship between O_2, H^+, CO_2 and HCO_3^- are central to the understanding of acid base balance and reflect the physiological importance of the CO_2/HCO_3^- buffer system." (Intensive and Critical Care Nursing (2008) 24, 30.)
- The CO_2/HCO_3^- buffer system takes up extra H^+
- In the presence of carbonic anhydrase (in RBC's) the following occurs:
  - $CO_2 + H_2O$ « » H_2CO_3 « » $H^+ + HCO_3^-$
    - (Carbonic Acid)

A Closer Look

- Respiratory –
  - Respiratory issues result in an increase in CO_2 (volatile acid) which results in an increase in H^+ through the generation of carbonic acid.
  - The lungs play a MAJOR role in maintaining H^+ concentration
  - The lungs maintain acid base balance by:
    - Removing CO_2 (CO_2 is a waste product of metabolism)

A Closer Look

- Metabolic –
  - Metabolic problems occur for various reasons such as poor renal function or an increase in non-respiratory acid production (ex lactic acid). This results in decreased HCO_3 and therefore increased H^+
  - The kidneys maintain acid base balance by:
    - Reabsorbing HCO_3 and other buffers
    - Excreting H^+ and other acids
    - End result is elimination of the daily load of nonvolatile acids from normal metabolism

Acute vs. Chronic Maintenance

- Acute Maintenance
  - Buffers
  - Ventilation (can change pH very quickly)
- Chronic Maintenance
  - Dependent on the balance between the production or intake of acid, and its metabolism and excretion
  - Successful long term maintenance is dependent upon RENAL excretion of nonvolatile acid

Normal ABG values

	< 48 hours	> 48 hours
ph	7.30-7.40	7.35-7.45
PCO2	35-45	35-45
PO2	50-80	50-80
HCO3	19-22	20-26
BE	-2 -+2	-2 -+2

Acidosis vs. Alkalosis

- Acidosis – pH is less than 7.35
- Alkalosis – pH is more than 7.45
- For purposes of today's lecture – we will use the > 48 hour normal values
- Select patients such as those with Chronic Lung Disease often have acceptable values well outside of the "normal" range

Respiratory Acidosis

- CO_2 is the respiratory component of acid base, think of it as an acid
- pH < 7.35 and CO_2 is > 45
- The problem is in the LUNG, inadequate ventilation

Respiratory Acidosis

- V/Q mismatch
  - Airway obstruction, MAS
- Decreased Compliance
  - HMD, CDH, RDS
- Injury to thorax
  - Pneumothorax, phrenic nerve paralysis
- CNS
  - Narcotics, asphyxia, intracranial hemorrhage, apnea, prematurity

Metabolic Acidosis

- HCO3 is the metabolic component, think of it as the base
- pH < 7.35 and HCO3 <20
- The problem is outside of the lung
- NOTE –
  - pH and HCO3 have direct relationship. Increase HCO3 = increase pH
  - pH and CO2 have an inverse relationship Increase CO2 = decrease pH

Metabolic Acidosis

- Loss of HCO_3
  - Prematurity, renal tubular acidosis, diarrhea
- Excess Acid Load
  - Inborn errors of metabolism
  - Renal failure (increased organic acids)
  - Lactic acidosis (hypoxia or hypoperfusion)
    - Respiratory distress
    - CHD
    - Sepsis
    - Shock

Respiratory Alkalosis

- pH > 7.45, CO_2 <35
- Causes
  - Excessive mechanical ventilation
  - Hypoxemia
    - Increased alveolar ventilation
  - Pain
    - Patient has increase in respiratory rate, driving down CO_2

Metabolic Alkalosis

- pH > 7.45, HCO3 > 26
- Causes
  - Loss of acid
    - Gastric suctioning
    - Vomiting
  - Diuretics
    - Renal loss of H+ ion
  - Giving too much HCO3

Base Excess

- Base excess shows the excess or deficit of bicarbonate and also incorporates the buffering action of RBC's.
- If HCO_3 is below normal, a base deficit (negative base excess) is present.
- When base deficit approaches -10 $NaHCO_3$ administration may be considered.

$NaHCO_3$ Administration

- May use in documented metabolic acidosis with large base deficit
- Usually 1-2meq/kg
- May mix 1:1 with sterile water
- Administer over 30 minutes
- Monitor patient
- PCO_2 may increase with HCO_3 administration

Interpreting ABG's

- PCO2- the respiratory factor
  - Indirectly related to pH
  - Increased PCO2 = acidosis (a)
  - Decreased PCO2 = alkalosis (A)
- HCO3 – the metabolic factor
  - Directly related to pH
  - Increased HCO3 = alkalosis (A)
  - Decreased HCO3 = acidosis (a)

How can we make it easy???

- Give each component in the ABG an acidosis (a) or alkalosis (A) assignment
- If the letter assigned to PCO2 matches the pH it is a Respiratory problem
- If the letter assigned to HCO3 matches the pH it is a Metabolic problem
- If both HCO3 and PCO2 match the pH it is a mixed problem

Compensated vs. Uncompensated

- Compensated – the pH has returned to normal range in the presence of other abnormal values
- Uncompensated – the pH has not returned to the normal range of 7.35-7.45
- Partial compensation – abnormal values are present, some compensation has occurred but the pH has not returned to normal

Practice

ABG	Value
pH 7.1	a
PCO2 – 38	-
HCO3 – 10	a
PO2 - 58	

Uncompensated Metabolic Acidosis,

Normal PO2

Practice

ABG	Value	
pH 7.25		a
PCO2 – 80		a
HCO3 – 21		–
PO2 – 28		

Uncompensated Respiratory Acidosis, Low PO2

Practice

ABG	Value
pH 7.41	-
PCO2 – 39	-
HCO3 – 21	-
PO2 – 63	

Normal ABG

Practice

ABG	Value
pH 7.36	a
PCO2 – 25	A
HCO3 – 14	a
PO2 – 38	

Compensated Metabolic Acidosis, Low PO2

Practice

ABG	Value
pH 7.02	a
PCO2 – 55	a
HCO3 – 14	a
PO2 – 32	

Mixed Acidosis, Low PO2

Practice

ABG	Value
pH 7.30	a
PCO2 – 80	a
HCO3 – 21	-
PO2 – 52	

Uncompensated Respiratory Acidosis, Normal PO2

Section 2 - In the NICU

Airway Management and Mechanical Ventilation

The terms…

- PIP – Peak pressure reached during inspiration
  - The smaller the baby the lower the starting pressures should be
  - High PIP is correlated with barotrauma, volutrauma, and CLD
- TV – Total volume achieved during inspiration
  - 4-6 ml/kg
- PEEP – Positive End Expiratory Pressure
  - Keep alveoli open during expiration
  - Start at 4-6 cm H2O
- IT – Inspiratory time
  - Range 0.3-0.4
- RR – Breaths per minute
  - Range 30-60

The terms…

- Ventilation mode – SIMV, A/C, PC, PS, PCV+, PRVC, VG
- Compliance = $\frac{\Delta Volume}{\Delta Pressure}$
- Resistance = $\frac{\Delta Pressure}{\Delta Flow}$

Conventional Ventilation

- Problems with PO2 –
  - Increase O2 concentration
  - Improve mean airway pressure (MAP)
    - Increase PIP
    - Increase IT
    - Increase PEEP

Conventional Ventilation

- Problems with PCO2 = Change patient's minute ventilation (MV)
- MV = RR x TV
- Improving MV
  - Increase Rate
  - Increase PIP
  - Intubation and Mechanical Ventilation are often used to better control MV

How do the “modes” work?

- SIMV, A/C, PC, PS, PCV+, PRVC, VG
- LOTS to choose from
- Some modes are dependent on the type of ventilator used

Synchronized Intermittent Mandatory Ventilation (SIMV)

- Patient triggered ventilation
- Breaths are synchronized to the onset of a spontaneous patient breath (once trigger threshold is met)
- Breaths are delivered at a fixed rated if patient does not have adequate effort
- How it works –
  - An assist window opens in which the patient can trigger an assisted breath. If the pt triggers the breath during the window a ventilator assisted breath is delivered. Any other triggered breaths in the window will be at level of PEEP
  - Mechanical breaths (un-triggered) are delivered if the patient does not trigger a breath during the window

Assist/Control Ventilation (A/C)

- Mechanical breaths are either patient (assist) or ventilator (control) initiated
- May also be called patient-triggered ventilation
- How it works
  - When a patient meets the trigger threshold, the ventilator initiates a mechanical breath
  - Control breaths are in place in case patient does not trigger
  - Back up breaths are like IMV (intermittent mandatory ventilation) breaths
  - Control breaths supply minute ventilation if patient does not trigger

Pressure Control

- Mechanical breaths are delivered at a set PIP, set IT, and variable inspiratory flow
- Can be used with IMV, SIMV, or A/C
- Constant PIP
- Variable TV
- Decelerating flow waveform
- Advantage – Improved gas distribution, laminar flow
- Disadvantage - Delivered TV is variable. Have to monitor for changes in compliance

Volume Control

- Preset Volume is delivered in every breath
- Because of un-cuffed OETT's volume can be lost
- Volume is controlled or limited
- Breaths can be patient triggered or machine initiated
- Can be used with IMV, SIMV, A/C
- Advantage – TV is constant even if compliance changes
- Disadvantage – Patients with small tidal volumes may have difficulty triggering, OETT leaks can cause loss of pressure

Combining the Best of VC and PC

- Some ventilators provide modes that have advantages of both pressure control and volume control
  - PRVC
  - SIMV + VG

HFOV (The Oscillator)

- High Frequency Oscillatory Ventilation
- Diaphragmatically sealed piston driver
- Active expiration
- No sigh breaths
- Initial rate – 10 Hz (600 bpm) to 15 Hz (900 bpm)
- IT – 33%
- Power – Dependent on Pt size, can adjust to improve ventilation. Increase Power = increase Δ P (amplitude) = improved ventilation.
- Δ P should be high enough to have good chest wiggle
- Bias Flow 10-15 lpm (up to 20 on large patients)
- MAP (Paw) is like PEEP

HFOV

- Problems with PO2 –
  - Increase MAP (Paw)
  - Increase FiO2
- Problems with PCO2 –
  - Alveolar Ventilation (MV)= (TV^2) x Rate
  - Increase Δ P (Amplitude)
  - Reduce frequency in Hz
    - 60 breaths per min = 1 Hz
    - <u>Decrease</u> rate to <u>increase</u> support on HFOV
    - A lower rate produces higher tidal volumes

HFJV (The Jet)

- High Frequency Jet Ventilation
- Flow interruptor, uses pinch valve to generate high frequency pulses
- Expiration is passive
- Sigh breaths from conventional ventilator
- PEEP level from conventional ventilator
- Initial PIP and Rate on Jet is dependent on lung pathology
  - A Jet Rate of 420 is the default
  - May need lower rate (240-360) for larger patients
- IT 0.02 sec

HFJV

- Problems with PO2 –
  - Increase MAP by increasing PEEP
  - Optimize PEEP before going up on other settings
  - Increase back up rate on conventional vent
  - Increase IT on conventional vent
  - Make sure patients lungs are not OVEREXPANDED
  - Increase FiO2

HFJV

- Problems with PCO_2 –
  - Alveolar Ventilation (MV)= (TV^2) x Rate
  - CO_2 primarily affected by Δ P
    - Δ P = PIP – PEEP
  - CO_2 problems = increase Δ P by increasing PIP
  - Remember your Δ P is affected by PIP and PEEP. Any change in either of these factors will alter Δ P
  - Frequency in Hz
    - Rate has smaller effect on CO_2 than Δ P
    - Increase rate to increase support on HFJV
      - Increase by 40-80 bpm as needed to improve ventilation without increasing PIP

Section 3 - In the NICU

What's up with Non-Invasive Ventilation?

CPAP

- CPAP = Continuous Positive Airway Pressure
- Pressure is applied throughout inspiration and expiration
- Goal – maintain lung volume, improve oxygenation and ventilation
- CPAP level of 5 – 6 is common. May increase but not above 10
- CPAP is usually delivered –
  - Mask (in delivery room)
  - Nasal Mask –
  - Nasal Prongs –

CPAP

- Effects of CPAP –
  - Decreased upper airway resistance by mechanically splinting airways open
  - Improves lung compliance in patients with respiratory pathology and therefore decreased work of breathing
  - By increasing MAP, CPAP reduces O2 requirements
  - Conserves surfactant at the alveolar level

CPAP

- Contraindications
  - Recurrent apnea
  - Ventilatory failure
    - High O2 requirement, severe distress, high CO2, acidosis
  - Upper airway anomaly
  - Cardiovascular instability
  - Complications – nasal trauma

NiPPV

- Similar to CPAP in that the patient is not intubated
- Has set PEEP but ALSO increase in pressure during inspiration
- Has benefits of CPAP but adds positive pressure breaths to the mix
- Delivers larger TV
- Can lead to reduction in patient respiratory rate and effort
- Delivered with bi-nasal prongs
- Not recommend by face mask in neonates

NiPPV

- Settings – Similar to conventional ventilation with endotracheal tube. Some prefer to stay with lower rates and pressure because it is easier on abdomen. IT may be extended to 0.5
- Benefits of NiPPV
  - Use to avoid endotracheal intubation
  - Can use post extubation
  - To treat patient with apnea
  - Can decrease chronic lung disease

NiPPV

- Failure of NiPPV – worsening ABG's with increasing settings. Need for intubation and mechanical ventilation
- Complications
  - Abdominal distension
  - Tube blockage secondary to secretions
  - Nasal damage from prongs
  - Uncommon – pneumothorax or gastric perforation, if used incorrectly

Where does Heated High Flow NC fit in to the picture???

Section 4 - In the NICU

Chronic Lung Disease and the word on the street….

Article Review

- Bubble Nasal CPAP, Early Surfactant Treatment, and Rapid Extubation Are Associated with Decreased Incidence of BPD in Very-Low-Birth-Weight Newborns: Efficacy and Safety Considerations – Friedman et. al. – Respiratory Care Magazine
  - Findings – prevention of alveolar atelectasis in surfactant-deficient lungs is better than recruiting lungs that are collapsed. Early intervention and treatment is key!
  - The use of Bubble CPAP with early surfactant administration and rapid extubation decreased the incidence of BPD in ELBW patients
  - There is a great need to study different types of CPAP systems to demonstrate if this benefit is specific to bubble CPAP or if it can be reproduced in other forms of nasal CPAP.

Article Review

- Impact of Implementing 5 Potentially Better Respiratory Practices on Neonatal Outcomes and Costs – Levesque et. al. Pediatrics
  - Findings –The use of bubble CPAP (including the delivery room), strict intubation criteria, strict extubation criteria, and prolonged CPAP use were beneficial in patients less than 33 weeks gestation
  - These practices decreased the need for mechanical ventilation, surfactant, and supplemental oxygen
  - There was also a reduction of hypotension in the patient population

Current Trends in Neonatal care

- Gentle aeration
  - Bag with low pressure in delivery room
  - Use of T-Piece resuscitator when possible to maintain low pressure
  - CPAP or NiPPV when possible to prevent intubation
  - CPAP is the mainstay of gentle ventilation
  - If surfactant replacement is given - intubation and then quick extubation after procedure if possible
- Low O2 concentration
  - Blender O2 in delivery room and in nursery
  - Start with 21% O2 and titrate up if needed
  - Pulse ox to target acceptable SaO2 levels for age and gestation

Questions???

Remember

- It’s all just a balancing act!!!