Transitioning from Snapshot to Continuous Neonatal Monitoring: Reducing Risk, Comorbidities, and Invasive Ventilation in the NICU

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Disclosures

- Consulting fee Radiometer of America
Objectives

- Review the tools available to enable the bedside caregiver to make clinical decisions
- Demonstrate why continuous bedside decision-making improves patient outcomes
- Analyze the reasons why continuous monitoring accelerates the weaning of invasive ventilation
- Illustrate how continuous monitoring can reduce comorbidities common in the NICU population
Step Back in Time

- 1970's
  - CPAP, Baby birds, blood gasses
- 1980's
  - Electronically cycled vents, Transcutaneous monitor, surfactant
- 1990's
  - Pulse oximeter, high frequency ventilators
- 2000’s
  - Nitric Oxide
What we thought we learned 1970 &1980s

- Ventilator pressure was bad
  - PIE 90% mortality
  - Pneumothorax
- Reliance on blood gas samples
  - Blood gases were obtained with obvious changes in patient condition
  - We only managed the ventilator when a blood gas was done
Transcutaneous Monitoring

- Birth of TCOM gave us insight on PaO₂ and PaCO₂
- Values out of range was an indication to obtain a blood gas
- We could use to help diagnose PPHN with pre and post ductal TcO₂ monitoring (continued current practice)
Transcutaneous Monitoring

- Also gave some bad experiences that we have not forgotten
  - Site burns
  - Calibrations that took a long time
  - Calibrating every 2-4 hours
  - Skin irritation/trauma from adhesive rings
- These were on 28-30 week gestational infants
Early Continuous Pulse Oximetry

- In lighted us that neonate’s oxygen needs was constant changing
- Give higher oxygen levels to prevent desaturations
- Ok to keep oxygen saturations 90-100%
- Still only made ventilator changes with blood gas results
Birth of Bedside Decision Making

- Pulse oximetry, severe retinopathy, and outcome at one year in babies of less than 28 weeks gestation
- Chow LC et al, Pediatrics 2003
- Can changes in clinical practice decrease the incidence of severe ROP in VLBW infants

- Moved decision making care from Physicians to bedside care giver.
Birth of Bedside Decision Making

- Neonates oxygen needs is continuously changing
- Physician orders must be written that allows the bedside care giver the ability to maintain optimal oxygenation
- Lim K et al. J Pediatrics
- 31% of time kept 88-92%
Birth of Bedside Decision Making

- Is there an NICU in our country that does not place a premature infant receiving oxygen on a pulse oximetry?
- WHY?
Birth of Bedside Decision Making

- Prevent **Retinopathy of prematurity (ROP)**
- Lower saturation ranges decreased BPD
- Ethically
- Legal protection
Question

- What is worse
  - Retinopathy of Prematurity (ROP)
  - Intra Ventricular Hemorrhage (IVH)
  - Periventricular Leukomalacia (PVL)
  - Cerebral Palsy (CP)
Then ???

- How did two studies change the practice on how we deliver oxygen but 10 studies with much worse comorbidities have not changed how we monitor CO$_2$ and protect the brain?
What Happened to: Ethical Legal Protection

- Evidence of CO$_2$ contributing to IVH, PVL
- As PaO$_2$ contributing to ROP
- Yet every neonate gets a pulse oximeter but not every ventilated neonate get CO$_2$ monitoring.
Carbon Dioxide

- PaCO$_2$ has a direct impact on cerebral blood flow
  - ↑ PaCO$_2$ ↑ cerebral blood flow
    - Increase risk of adding to severity of Intra Ventricular Bleed (IVH)
  - ↓ PaCO$_2$ ↓ cerebral blood flow
    - Increase risk of periventricular leukomalacia (PVL)
      - Brain white matter necrosis
      - Often leading to Cerebral Palsy
Show me the Evidence
Collins MP et al, Pediatr Res 2001;50:712

- Hypocapnia & other ventilation related risk factors for CP in LBW infants. 777 infants with neuro assessment at 2 years
  - 2.3% disabling CP in non ventilated infants
  - 9.4% disabling CP in ventilated infants without CO\(_2\) <35
  - 27.5% disabling CP in ventilated infants with CO\(_2\) <35
- Other risk factors, hyperoxia, prolong ventilation
Murase M, Paediatr 2005;94:85

- Early hypocarbia of preterm infants: its relationship to PVL and CP
  - 115 very low birth weight infants
  - ABG drawn at 3, 6, 12, 24, 48 hours
  - 2 out of 5 PaCO₂ <25 considered severe early hypocarbia
- Severe hypocarbia was associated with both CP and late-onset PVL
Erickson SJ et al, j Paediatr Child Health 2002;38:560

- Hypocarbia in the ventilated preterm infant & its effect on IVH & bronchopulmonary dysplasia
  - Retrospective cohort analysis of 314 infants
- Infants with PaCO₂ < 30 at any time in the first 48 hours had an increased risk of IVH or PVL
- Infants with at least 3 ABGs with PaCO₂ < 30 had an increased risk of BPD
Shankaran S et al, Pediatrics 2006;118:1654

- Cumulative index of exposure to hypocarbia and hyperoxia as risk factors for PVL in low birth weight infants
  - Low CO₂ exposure in 6 hour blocks
  - Cumulative total of blocks of time vs amount of CO₂,35
- Cumulative exposure to hypocarbia and not hyperoxia was independently related to risk of PVL

- $\text{PaCO}_2$ and neurodevelopment in extremely low birth weight infants
  - Relationship between $\text{PaCO}_2$ in the first 4 days of life and neurodevelopment at 18-22 months
  - 400 infants 400gm to 1 kg
- Extreme fluctuation in $\text{PaCO}_2$ and higher max $\text{PaCO}_2$ are associated with worse neurodevelopmental outcomes
Thome UH et al, Biol Neonate 2006;90:218

- Outcome of extremely preterm infants randomized at birth the different PaCO₂ targets during the first seven days of life
  - Randomized PaCO₂ ranges either 35-45 or 55-65
  - Study stopped after 1/3 enrollment
- Minimal ventilation was associated with trends towards higher mortality and incidence of neurodevelopmental impairment.
Wiswell TE et al, Pediatrics 1996;98:918

- Effects of hypocarbia on the development of cystic PVL in premature infants treated with high frequency jet ventilation
  - 67 infants treated on HFJV
  - 18 developed cystic PVL
  - CO2 less than 25

- Infants with cystic PVL were more likely to have significant cumulative hypocarbia
Both Extremes of Arterial Carbon Dioxide Pressure and the Magnitude of Fluctuations in Arterial Carbon Dioxide Pressure Are Associated With Severe Intraventricular Hemorrhage in Preterm Infants

CONCLUSIONS:

- Both extremes and fluctuations of PaCO₂ are associated with severe intraventricular hemorrhage.
- It may be prudent to avoid extreme hypocapnia and hypercapnia during the period of risk for intraventricular hemorrhage.
Changing Practice

- Need evidence for best practice
- Evaluate your practice, do you have a problem
- Develop policy and procedures for changing practice
- Sell the program, lay out all the facts
- Educate, educate, educate
- Monitor results and share with stakeholders
2008 Retrospective Review Grade III & IV Intraventricular hemorrhage
Bundle to decrease IVH

- Transcutaneous monitoring on all invasive ventilated patient
- Decreased amount of blood clearance on line draws
- Delayed cord clamping at delivery
- Midline patient positioning 1st 72 hours
Transcutaneous Monitoring the present

Skin burns no longer an issue
Calibrations built into unit
Calibrations are quick
Units hold their calibration longer
Adhesive rings allow for reapplication without damaging skin
Results

- 2007/2008: Average 10 Severe Peri-Intraventricular Hemorrhage
- 2009: 7 Severe Peri-Intraventricular Hemorrhage
- 2010/2011: 4 Severe Peri-Intraventricular Hemorrhage
- Prior to bundle we were way above 50th percentile in state wide data base after implementation we dropped well below
Chronic Lung Disease

- Associated with total length of invasive ventilation
- Longer patient is on also relates to ventilator associated pneumonia VAP
- TC CO2 monitoring allows for constant ability to wean from ventilator
Why the drop in ventilator days?

- Ventilator changes were only made during blood gases
- Stable patients would get blood gas only 2-4 times a day
- Could not make a ventilator change without justifying with results
Financial Benefits for Decreasing Ventilator Days

- VAP increases cost
  - Pharmaceutical cost
  - Increase days in hospital
  - Will no longer be reimbursed if caused by hospital
- TcCO₂ decreases blood gasses
  - Decrease blood transfusions $
  - Decrease infections
  - Decrease cost of blood gas labor
- Decrease in staffing, nursing/respiratory
Financial Benefits for Decreasing Ventilator Days

- Total decrease in ventilator days 2009
  - 750-1500 gram patients went down from 25 to 10 days per patient for 45 patients = 675 vent days
  - >1500 gram patients went down from 8 to 4 days per patient for 138 patients = 552 vent days
  - Total drop in vent days = 1227 vent days for the year or 3.3 vent per day
Financial Benefits for Decreasing Ventilator Days

- Invasive ventilation 1:1 nursing, noninvasive ventilation 1:2
  - Estimated $613,500 saved 2009
    - $1000 per day for nursing for 1:1 care for 1227 vent days or $1.22 million
    - 1:2 nursing care for 1227/2 = 613.5 patient days or $613,500
- Patients >1500 grams majority had minimal respiratory services
  - 552 vent day for year = 1.5 vent per day or .5 therapist per shift
  - Equivalent to 2.5 FTE
- Patients 750-1500 grams = 675 vent days saw a moderate decrease in care. Difficult to compute in respiratory savings but still would be substantial annual savings
High frequency ventilation is dangerous if not monitored

- All mechanically ventilated patients should have CO$_2$ constantly monitored
- HFV can only have transcutaneous CO$_2$ monitoring
- HFV is known for CO$_2$ swings
HFO Settings

- Amplitude
  - Main adjustment for CO₂ removal
  - Can get CO₂ out of a rock
  - Initially look at chest wiggle for start
  - Must use Transcutaneous CO₂ monitoring
    - Early warning for change in chest wiggle
  - Cannot use EtCO₂
  - CO₂ removal very volatile
Normal changes in chest wiggle

- Secretion build up/clearance
- Change in patients position
  - Can cause large swings in both directions
    - TcO₂ 50-25 or 40-65
- Seizures
- Changes in PDA flow
- Just happens
HFO Caution Clinical Guidelines

- The patient’s TcPCO\textsubscript{2} and TcPO\textsubscript{2} or SpO\textsubscript{2} must be monitored continuously to insure that blood gases are at the proper level.

- Non-Invasive Blood Gases
- TcPO\textsubscript{2}, TcPCO\textsubscript{2} and SpO\textsubscript{2}
  - Non-invasive blood gas values should be checked continuously. This is particularly important in larger children who have more dead space and a greater metabolic demand on ventilation.
Current 1\textsuperscript{st} blood gas

- 85% with a TcCO\textsubscript{2} value with first gas
  - TcCO\textsubscript{2} not available
  - Leg only site for first application (not most optimal site)
    - Lines being placed
    - X-ray being taken
    - Easily comes off and under a sterile field we use some wrap to stabilize
- 70% PaCO\textsubscript{2} was with 5 points of TcCO\textsubscript{2}
- 82% PaCO\textsubscript{2} was within 10 points of TcCO\textsubscript{2}
- 40% Staff let TcCO\textsubscript{2} drift below 40
We do blood gases, why do we need a CO$_2$ monitor?

- Same reason why you have a Pulse oximeter, the patients oxygen requirements constantly change in between blood gas draws
- Getting a Blood gas result with either a very low or high CO$_2$ is too late, damage is done.
- Ventilator changes should be made proactive so your blood gases are always within the acceptable ranges
- Lawyers are already targeting CP patients
**24 hour view**

- Blood gasses are stable as we are being proactive with ventilator changes
- If we did not have TcCO₂ then possible 6-12 hour blocks with extremely low or high CO₂
- Blood gas frequency every 12 hours to Q daily or at times just PRN.
  - Decrease blood loss
  - Decrease in possible line induced infections
  - Drawing from arterial line can change blood pressure
Snap shot of the Blood Gas

- Pre pulse oximetry in the early 1980s
  - $\text{FiO}_2$ would only be changed with a blood gas
  - 28-30 week gestational age was the edge of survivability
  - ROP (RLF) was a major problem
- With age of pulse oximetry we now know their tissue oxygenation goes all over the place
- Continuous transcutaneous is now teaching us that $\text{CO}_2$ levels are also all over the place
  - Allows us also to be more proactive in removing invasive ventilation
  - Earlier warning for compromised neonate
Conventional Ventilation

- Pressure control / time cycle pressure limit
  - Tidal volumes constantly changing
  - TcCO₂ aids in making sure that changes in compliance is not resulting in too small or too large of tidal volumes by being a secondary alarm.

- Volume guarantee / Pressure regulated volume control
  - TcCO₂ aids in changes in leak around ET causing ineffective tidal volume delivery.
tcCO2 has also warned of us of a incorrect capillary blood gas

- Post op patient 30 minute after Blood gas
  - CBG CO₂ 74, TcCO₂ 43
  - Patient looked well ventilated, chest rise, b/s
- Repeat arterial blood gas
  - PaCO₂ 41, TcCO₂ 43
TcCO$_2$ early warning for shock/poor perfusion

- Do not want to over react to intermittent rises in TcCO$_2$, but a constant elevation or large spike warrants further assessment including a blood gas
Continuous monitoring relies on clinical knowledge

- Always correlate with patient condition
- Changes in TcCO\textsubscript{2} should also be correlated to changes to
  - Ventilation
  - Chest wiggle
  - Oxygenation
  - Breath sounds
Staff education

- How to interpret transcutaneous monitoring
- Recognizing errors in monitoring
  - Poor perfusion sites
  - Pressure on sensors
  - Air bubbles
- Trending with blood gases
- Poor perfused capillary blood gas
- If in doubt get a blood gas
Policy for staff to make adjustments on ventilation

- As you have the ability to make changes with pulse oximeters reading you must have the same with adjusting the ventilation component.
- Does not have to be built in order sets.
- Adjust SIMV/Amplitude to maintain PaCO₂ between ***-*** by way of TcCO₂ correlation.
- Adjust PIP to maintain tidal volume ***ml/kg as long PaCO₂ is within ****-*** by way of TcCO₂ correlation.
Hospitals Reimbursement tied to Performance

- CO₂ monitoring can help by decreasing ventilator days
  - Decrease opportunity of infection VAP
  - Decrease in Chronic lung disease
- Protocols need to be developed for 24/7 care
Review of the Objectives

- Review the tools available to enable the bedside caregiver to make clinical decisions
  - Clear evidence that both pulse oximetry and transcutaneous monitoring should always be used for the management during invasive ventilation in the neonatal population.
Review of the Objectives

- Demonstrate why continuous bedside decision-making improves patient outcomes
- Illustrate how continuous monitoring can reduce comorbidities common in the NICU population
  - Clear evidence that careful monitoring of patients' PaCO$_2$ on a continuous basis can decrease the incidence of IVH, PVL, CP when bedside care givers make proactive changes to invasive ventilation
Review of the Objectives

- Analyze the reasons why continuous monitoring accelerates the weaning of invasive ventilation
  - Demonstrated that the combination correct monitoring tools and policies to allow for proactive adjustments of invasive ventilation results in a shorten period on invasive ventilation.
Questions