Methods to Improve Ventilation and Other Techniques in Patient-Ventilator Management

Chapter 13

- After the initiation of ventilation and the initial assessments and documentation, review of ventilator graphics the concern focuses on improving ventilation and oxygenation and managing the patient-ventilator system
- Common to obtain an arterial blood gas after 20-30 minutes of stable ventilation

Correcting $PaCO_2$ abnormalities

- Ventilation is evaluated by pH, $PaCO_2$, HCO_3
- Common equations to make changes include:
  - Known $PaCO_2$ X Known Ve = Desired $PaCO_2$ X Desired Ve
  - $$\text{Desired Vt} = \frac{\text{Known PaCO}_2 \times \text{Known Vt}}{\text{Desired PaCO}_2}$$
  - $$\text{Desired f} = \frac{\text{Known PaCO}_2 \times \text{Known f}}{\text{Desired PaCO}_2}$$

Respiratory Acidosis

- Evidenced by an elevated $PaCO_2$ > 45mmHg and decreased pH <7.35
- Increasing the minute ventilation will decrease the $PaCO_2$
- Which to adjust first, volume or rate?
  - Keep Vt 8-12 ml/kg
  - Keep Pplat < 30cmH2O
  - Increase the IP in PCV or lengthen Ti (box 13-1, p. 259)
  - If volume and pressure are high, increase rate
- Examples 1-3 pages 259-260

Respiratory Alkalosis

- $PaCO_2 < 35$mmHg; pH >7.45
- Excessive alveolar ventilation
- Decrease Ve
  - First decrease rate
  - Then decrease vol (VC) or insp pressure (PC)
- Examples 1-2, page 261
- Respiratory alkalosis during spontaneous efforts (CMV 12, f=16) should you decrease rate?

Metabolic Disorders

Metabolic Acidosis

- ABG pH 7.0-7.34
- HCO_3 12-22mEq/L
- Struggle to lower $PaCO_2$ through hyperventilation – compensation
- Risk of muscle fatigue from increase WOB

- Metabolic Alkalosis
- ABG pH 7.45-7.7
- HCO_3 26-48mEq/L
- Alveolar hypoventilation is not often used as a compensatory mechanism - risk of hypoxemia

(as CO_2 ↑, PaO_2↓)

Metabolic Disorders

Metabolic Acidosis

- Causes
  - Ketoacidosis
  - Uremic acidosis/renal failure
  - Diarrhea – loss of HCO3
  - Renal loss of base
  - Overproduction of acid
  - Ingested toxins
- Treatment – therapy to reverse the cause of acidosis
  - Administration of alkaline agent
  - Ensuring vascular volume an cardiac output are normal
  - Assuring adequate oxygenation
  - Allow time for the normal metabolism of organic acids and time for the kidneys to replace HCO3

Metabolic Alkalosis

- Causes
  - Vomiting, nasogastric suctioning – loss of acid
  - Acid loss in the urine – diuretics
  - Potassium deficiency
  - Lactate acetate or citrate administration
  - Excessive bicarbonate
- Treatment – correcting the underlying cause of alkalosis
  - Carbonic anhydrate inhibitors
  - Acid infusion
  - Low bicarbonate dialysis
- Rare to see a compensated metabolic alkalosis

Clinical Rounds 13-1 p. 262

A 68 year old man is admitted to the hospital. He is placed on mechanical ventilation for acute respiratory failure compounded by a metabolic acidosis. It was found that he has a renal disorder. The physician orders peritoneal dialysis. In the interim, the physician wants the RT to target a pH of 7.35 with assisted ventilation. Initial assessment of the patient resulted in the following ABG: pH 7.22; PaCO2 38; HCO3 15; PaO2 98 on FiO2 .25. The ventilator settings are changed tot the following : VC-CMV f =24, Vt=800, FiO2=.25. ABG results on the new setting are pH 7.37, PaCO2 23, HCO3 13.5, PaO2 115. What is the problem and what would you suggest to correct this and still help the patient

(see the flow time waveform, p.262)

The flow time scalar shows that the flow does not return to zero during exhalation before another mandatory breath occurs. Auto-PEEP is present. It is important to check ventilating pressures and keep Pplat < 30cmH2O to prevent lung injury. The physician should be notified that, in an effort to normalize the pH, the high Ve is causing auto-PEEP.

Mixed acid-base disturbances

- pH can appear normal due to a combination of:

  Respiratory acidosis and metabolic alkalosis

  OR

  Respiratory alkalosis and metabolic acidosis

- Important not to correct the ABG values but focus on the underlying causes

Physiological Dead Space

- If a respiratory acidosis persists even after increasing alveolar ventilation, consider the possibility of increased dead space
- Pulmonary embolism, low cardiac output leading to low pulmonary perfusion
- High alveolar pressures (high PEEP, auto-PEEP/air trapping) can reduce pulmonary perfusion
- Normal Vd/Vt = 0.2-0.4; $\frac{(PaCO2-PECO2)}{PaCO2}$

  PECO2 = partial pressure of the mixed expired gases collected from a patient

  PECO2 ≠ PetCO2

- More common to measure PetCO2 and use the gradient between PetCO2 and PaCO2 (normal 1-5mmHg) {Ch 11 states 4-6mmHg}
- Decrease in the PetCO2 and an increase in the P(a-et)CO2 gradient suggests increased dead space

Intentional Iatrogenic Hyperventilation

- Historically used in patients with acute head injuries and increased ICP
- A reduction in CO_2 in the blood constricts cerebral blood vessels = decreased blood flow to the brain to help lower ICP
- Current guidelines do NOT recommend prophylactic hyperventilation during the first 24hrs ($PaCO_2 < 25$)
- May actually increase cerebral ischemia and cause cerebral hypoxia
- Hyperventilation may be needed for brief periods with acute neurological deterioration and elevated ICP
- Mild hyperventilation ($PaCO_2$ 30-35) may be used for ICP refractory to standard treatment

Permissive Hypercapnia

- Used in cases where it becomes impossible to maintain normal ventilation without risking lung damage from high volumes or pressures
- ARDS, COPD, status asthmaticus
- Deliberate limitation of ventilatory support to avoid lung over distention and injury of the lung

Permissive Hypercapnia

- Allow $PaCO_2 \geq 50$mmHg
- $pH \leq 7.30$
- Allow for a gradual change in values, abrupt increases are generally not tolerated
- Concern about the effects of the acidosis on other organ systems - monitor
- $\uparrow CO_2 = \downarrow O_2$; Right shifting of oxy-hemoglobin dissociation curve (reduced O_2 loading in the lungs) monitor oxygenation!
- High CO_2 stimulates the drive to breathe – may need sedation

Strategy:

1. Allow $PaCO_2$ to rise and pH to fall without changing the mandatory rate or volume, sedate the patient, avoid high ventilating pressures and assure oxygenation

2. Reduce CO_2 production by using paralytic agents, cooling the patient, and restricting glucose intake.

3. Administer agents to keep $pH > 7.25$

Permissive Hypercapnia Contraindications

- CO_2 is cerebral vasodilator = cerebral edema and increased ICP; not used in patients with head trauma and intracranial disease
- Cardiovascular instability: decreased myocardial contractility, arrhythmias, vasodilation and increased sympathetic activity; hard to predict the response of the cardiac system, should be used with caution

Secretion Clearance

- Suctioning is performed on an as needed basis
  - Auscultation reveals coarse rhonchi
  - Visually see secretions in the airway
- Size of suction catheters are in French units
- Limit the size of the catheter to ½ to ⅔ the internal diameter of the ET
  - Convert ET to French units then divide by 2:

    ET X 3 ÷ 2
- Provide 100% oxygen for 30 seconds prior to suctioning then follow with 100% oxygen for 1 minute – use the suction key on the ventilators
- Time of suctioning event should not exceed 15 seconds

Complications of Suctioning

- Check all connections to assure suction pressure is set correctly and working prior to suctioning
  - Adults -100 to -120 mmHg
  - Child -80 to -100 mmHg
  - Infant -60 to -100 mmHg
- Suctioning is very irritating – can result in coughing, bronchospasm, hemorrhage, airway edema, and ulceration of the mucosal wall; can also cause atelectasis, hypoxemia, cardiac arrhythmias
- Complications are related to the duration of suctioning, amount of suction applied, the size of the catheter, and whether oxygenation was provided appropriately

A few more points about suctioning

- In-line suction catheters – avoids disconnecting patient from the ventilator (esp with high FiO2, PEEP), risk of contamination every time the circuit is opened
- Continuous aspiration of subglottic secretions (CASS)– silent aspiration around the cuff does occur, use of this tube can ↓VAP
- Instilling saline – intent is to loosen/thin secretions, in reality it causes nosocomial infections (VAP), reduces oxygenation, causes irritations, and increases dyspnea *use judiciously*
- Assessment – document the amount, color, sputum characteristics, breath sounds before and after the event

Clinical Rounds 13-2, p.

During suctioning of a ventilated patient using a closed-suction catheter, the therapist notices a cardiac monitor alarm. The patient's heart rate has increased from 102 to 150 beats/min. What should the therapist do?

A sudden tachycardia is a possible complication of suctioning. The RT should immediately stop the procedure, provide oxygen (100%) and hyperventilate the patient, preferably using the ventilator to do so.

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(From Cairo JM, Pilbeam SP: *Mosby's respiratory care equipment*, ed 7, St Louis, 2004, Mosby.)

Administering Aerosols to Ventilated Patients

Factors to consider include:

- Type of aerosol generating device used
- Ventilator mode and settings
- Severity of the patient's condition
- Nature and type of medication and gas used to deliver it
- Indicated for bronchoconstriction or increased airway resistance

Review the Protocols for aerosol delivery during mechanical ventilation

MDI	SVN
page 275	page 276

Patient Response

Improvement following bronchodilator therapy can be seen by

- Reduced peak inspiratory pressure
- Reduced transairway pressure
- Increase in peak expiratory flow rate
- Reduction in auto-PEEP levels

Clinical Rounds 13-3 p. 277

Following administration of 2.5 mg albuterol by SVN the RT evaluates pre and post parameters and notes the following:

Pre-treatment: PIP 28 cmH2O

Pplat 13 cmH2O

Pta 15 cmH2O

PEFR 35 L/min

Post-treatment: PIP 25 cmH2O

Pplat 18cmH2O

Pta 7 cmH2O

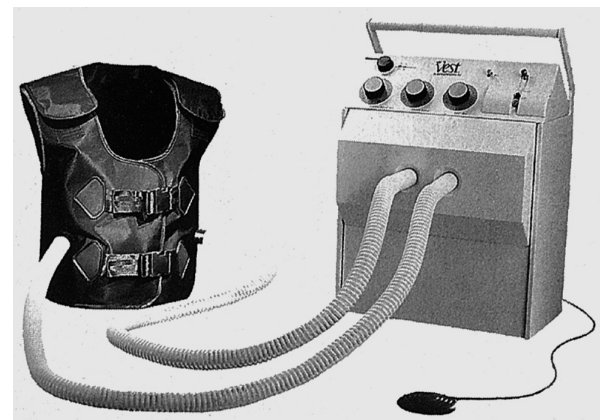
PEFR 72 L/min

Did the treatment reduce the patient's airway resistance?

Yes, the PIP decreased, the Pta is decreased by almost 50% and the PEFR increased by more than 50%.

Chest Physiotherapy

- Positioning can be complicated with mechanical ventilation, care must be taken to avoid accidental extubation
- Assure patient comfort
- May use The Vest Airway
- Clearance System



(Courtesy Hill-Rom Services, Inc., St Paul, Minn.)

- Use to clear airway secretions otherwise not able to be obtained with routine suctioning

Body Positioning

- Immobilized patients on mechanical ventilation require frequent turning to prevent atelectasis, pulmonary complications, as well as decubitus ulcers
- Kinetic beds allow continuous rotation, watch for accidental disconnection, extubation
- Body positioning can benefit patients with pulmonary disorders to optimize ventilation and perfusion

Kinetic Beds – RotoProne® from KCI

Prone Positioning

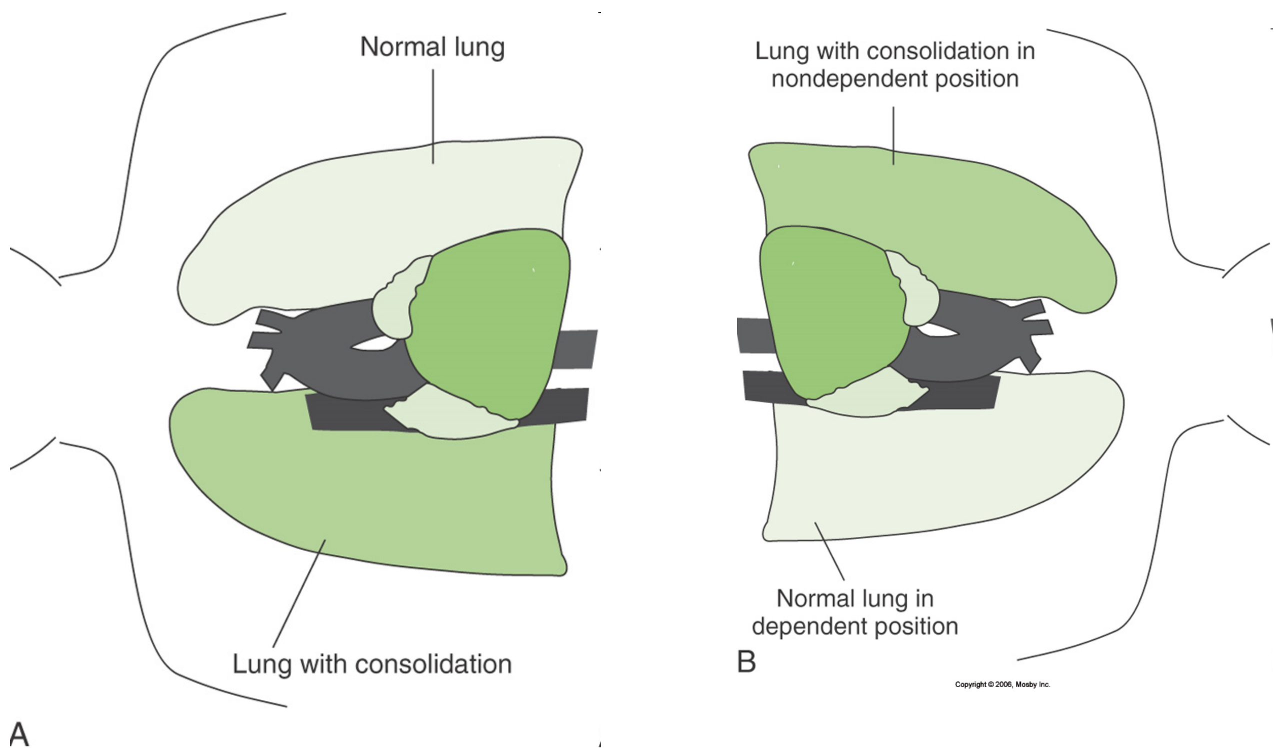
- May improve oxygenation and decrease the shunt present in the lungs
  - Blood is redistributed to areas that are better ventilated
  - Blood redistribution may also improve alveolar recruitment in previously closed areas of the lung
  - Redistribution of fluid and gas results in an improved relation between ventilation and perfusion
  - Prone positioning changes the position of the heart so it no longer puts weight on the underlying lung tissue
  - Pleural pressure is more uniformly distributed which could improve alveolar recruitment
  - Prone positioning changes the regional diaphragm motion
- Not all patient’s respond equally to prone positioning

Protocol for Prone Positioning

- Complications must be weighed against the advantages
- Technically challenging move, requires a team of at least 4 caregivers, must watch and secure all lines
- May require more sedation, even paralysis
- Attention to skin condition and pressure points is necessary
- Hemodynamic instability and oxygen desaturation may occur with repositioning

Unilateral Lung Disease Positioning

- “GOOD LUNG DOWN”
- Optimize ventilation and perfusion matching, dependent region is better perfused



Clinical Rounds 13-4, p. 283

A patient with pneumonia on the right side is receiving mechanical ventilation. The nurse repositions that patient on the right side for a procedure and the pulse oximetry low-oxygen alarm activates. What is the most likely cause of this problem?

The most likely cause is a ventilation/perfusion mismatch caused by rotation of the affected lung in the dependent position. With unilateral lung disease, it is best to position the good lung down. Another possible problem is thromboembolism (clots moved) or a compromised airway

Circuit Changes

- Historically changed frequently to avoid a source of infection
- Studies actually show that maintaining the integrity of the circuit is more advantageous for decreasing infections
- AARC CPG for care of the ventilator circuit

Ventilator circuits should not be changed routinely for infection control purposes. The maximum duration of time that circuits can be used safely is unknown.

Evidence is lacking related to ventilator-associated pneumonia (VAP) and issues of heated versus unheated circuits, type of heated humidifier, method for filling the humidifier, and technique for clearing condensate from the ventilator circuit.

Although the available evidence suggests a lower VAP rate with passive humidification than with active humidification, other issues related to the use of passive humidifiers (resistance, dead space volume, airway occlusion risk) preclude a recommendation for the general use of passive humidifiers. Passive humidifiers do not need to be changed daily for reasons of infection control or technical performance. They can be safely used for at least 48 hours, and with some patient populations some devices may be able to be used for periods of up to 1 week.

The use of closed suction catheters should be considered part of a VAP prevention strategy, and they do not need to be changed daily for infection control purposes. The maximum duration of time that closed suction catheters can be used safely is unknown.

Clinicians caring for mechanically ventilated patients should be aware of risk factors for VAP (eg, nebulizer therapy, manual ventilation, and patient transport).

[Respir Care 2003;48(9):869–879. © 2003 Daedalus Enterprises]

Clinical Rounds 13-5 p.

The RT caring for a mechanically ventilated patient has just completed a ventilator system check when a family member comes into the patient's room. The family member comments that the plastic tube on the patient's chest (in-line closed suction catheter) is full of sticky yellow stuff. She thinks the therapist should do something about it. How do you think the therapist should respond?

The RT should probably agree with the family member and change the catheter. The closed suction catheter is part of the ventilator circuit and needs to be changes if it mechanically malfunctions or becomes soiled. Even though the closed suction catheter may have been changed recently, if its appearance is bothering a family member it is reasonably to comply with their request. Changing visibly soiled circuit components is appropriate

Final Considerations

- Sputum Infection
  - Keep HOB elevated, examine sputum specimen when WBC>10,000/ cc^2, culture and sensitivity
- Fluid Balance
  - Monitor input and output, 50-60 mL/hr normal urine production, watch for overhydration or dehydration
- Psychological and Sleep Status
  - Reassure the patient, provide as much respect and privacy as possible
  - Sleep disturbances are almost unavoidable
  - Patients will respond in unusual or atypical ways
- Patient Comfort and Safety
  - Be prepared for emergencies, anticipate problems
  - Make every effort to provide patient comfort since so much of what they are experiencing is painful both physically and emotionally
  - “patient-centered mechanical ventilation”

Transport of the Mechanically Ventilated Patient

- Every effort must be made to keep the patient stable and provide the same level of care – equipment, medication, and personnel
- Benefits of transport must outweigh the risks