

Update on Ventilators: Remembering Everything You Forgot From Residency



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HOPEFULLY WE WON'T NEED
THESE AGAIN →



CDC

http://www.aap.org/en-us/PublishingImages/polio-ironlung_lrg.jpg

Objectives



- Review Standard Ventilator Modes and Settings and effect on gas exchange
- Case Based Learning Regarding Common conditions needing Ventilators
- Identify what to trouble shoot when things go awry

General benefits of MV



- **Improves Gas exchange**
 - Improves V/Q matching
 - Primarily by decreasing physiologic shunting
- **Decreases Work of breathing**
 - Resting the muscles of respiration
 - Helps overcome altered lung mechanics (increased resistance, decreased compliance) or increased respiratory demand (i.e. fever)

Basic Vent Modes



- **Volume Modes**
 - AC (some variants- VC plus, PRVC)
 - CMV
- **Pressure Modes**
 - Pressure Support
 - CPAP
- **Hybrid/Other Modes**
 - SIMV
 - PCV
 - APRV
 - Others

Types of breaths



- Defined by combination of 3 features
 - Trigger
 - ✦ Timed (Vent initiated)
 - ✦ Patient effort
 - Target- flow of air into lung
 - ✦ Pre-determined Flow Rate
 - ✦ Pressure Limit
 - Termination (end inspiration)
 - ✦ Volume limited
 - ✦ Time limited
 - ✦ Flow limited

Modes of mechanical ventilation

Mode	Breath strategy (target)	Trigger		Cycle (breath termination)	Types of breath		
		Ventilator	Patient		Mandatory	Assisted	Spontaneous
CMV	Volume-limited	Yes	No	Volume	Yes	No	No
	Pressure-limited	Yes	No	Time	Yes	No	No
AC	Volume-limited	Yes	Yes	Volume	Yes	Yes	No
	Pressure-limited	Yes	Yes	Time	Yes	Yes	No
IMV	Volume-limited	Yes	Yes	Volume	Yes	Yes*	Yes
	Pressure-limited (also called APRV)	Yes	Yes	Time	Yes	Yes*	Yes
PSV	Pressure-limited	No	Yes	Flow, pressure, or time	No	Yes	No
CPAP		No	Yes	Flow	No	Yes	No
Tube compensation		No	Yes	Flow	No	No	Yes

Types of breaths:

Mandatory: Breaths are initiated by the ventilator and the ventilator performs the work of inspiration for those breaths

Assisted: Breaths are initiated by the patient, but the ventilator performs at least some of the work of inspiration for those patient initiated breaths

Spontaneous: Breaths are initiated by the patient and the patient performs the entire work of inspiration for those patient initiated breaths

CMV: controlled mechanical ventilation; AC: assist control; IMV: intermittent mandatory ventilation; PSV: pressure support ventilation; CPAP: continuous positive airway pressure; APRV: airway pressure release ventilation; BPAP: bilevel positive airway pressure.

* Note that there is overlap between the types of breaths that can be generated during various modes of ventilation. This overlap is dependent on the ventilator settings. As examples, APRV and IMV are capable of assisted breaths (pressure support added) or spontaneous breaths (no pressure support added). Both assisted and spontaneous breaths depend on the patient's ability to trigger the ventilator.

QUIZ TIME



- What can you set? (depending on mode)
 - FiO₂
 - PEEP
 - Tidal Volume
 - Respiratory Rate
 - Pressure Support
 - Inspiratory Time
 - Flow Rate
- Which effects Airway Pressures
 - Pretty much all except FiO₂
- Which Variables effect Oxygenation?
 - Fio₂
 - Peep
 - Lesser Degree TV
- Which Effect Ventilation
 - TV
 - RR
 - PS

ABG Adjustments

pH / PCO₂ / pO₂ / ox sats

- Which Effect Ventilation?

- TV
- RR
- PS

- Which Variables effect Oxygenation?

- Fio₂
- Peep
- Lesser Degree TV

Case based Learning



- COPD
- Asthma
- ARDS
 - Covid specifics from SCCM guidelines and Italy experience
- Sepsis

Case based Learning



- **COPD**
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COPD (simple first case)



- 78 yo M with a history of oxygen dependent (normally 2L) COPD, presents with increased dyspnea and wheezing for the past 3 days.
- He complains of increased DOE and states he can't breathe
- Over last 2 days he has had increased rescue inhaler use without significant benefit
- He comes to the ER with significant dyspnea and is hypoxic to 86% on his 2L



- Gets Duoneb treatment and Gets ABG
- 7.25/84/62 and places on NIPPV
- Obviously, this is a vent lecture so the patient is going to fail NIPPV
- 1 hour later the ABG is 7.14/102/85 and he gets tubed via RSI

Question #1 (assume 70 kg)



- Which vent settings is the most appropriate to start the patient on?
- A) CMV TV 500 RR 14 PEEP 5 FiO₂ 100%
- B) CMV TV 700 RR 12 PEEP 5 FiO₂ 50%
- C) PS 15 PEEP 8 FiO₂ 50%
- D) CMV TV 500 RR 20 PEEP 8 FiO₂ 60%
- E) Let Respiratory Therapy Decide

Question #1



- Which vent settings is the most appropriate to start the patient on?
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- C) PS 15 PEEP 8 FiO₂ 50%
- D) CMV TV 500 RR 20 PEEP 8 FiO₂ 60%
- E) Let Respiratory Therapy Decide

CMV TV 500 RR 14 PEEP 5 FiO₂ 100%



- Recheck in 1 hour
- ABG now shows 7.18/98/268
- What changes would you make if any?
 - ? TV
 - ? RR
 - ? PEEP or FiO₂
- What is the patient doing? I.e RR, Peak and Plateau pressures

Peak and Plateau Pressures



- **Peak Pressures**
 - Measures airway resistance and lung compliance
- **Plateau Pressures**
 - Measure lung compliance only
 - Typically shoot for < 30 cm H₂O which lowers risk of pulmonary barotrauma
- **We worry more about Plateau pressures than Peaks (must do inspiratory hold to measure plateau)**
 - Peaks the machine calculates breath to breath
 - Obviously if Peak < 30 , so is plateau

Peak is always higher than Plateau



- If elevated and wide delta (> 5)
 - Usually a resistance problem (ETT or small airways)
 - Examples- Biting the tube, small ETT diameter, bronchospasm from asthma/COPD
 - Treatments can be based on probable cause
 - ✦ Bite blocks, larger ETT tubes, suctioning, bronchodilators
- If elevated and narrow delta (< 5)
 - Usually a lung compliance problem
 - Examples- ARDS, also pneumothorax, severe Fluid overload
 - Treatments above
 - ✦ LTVV ventilation, diuresis, chest tube

Back to our patient (7.18/98/268)



- Patient breathing 14 (he was RSI)
- TV 600 RR 24 PEEP 5 FiO₂ of 50%
 - Settings on this show a Peak Pressure of 43 and plateau of 26
- What can you do?
 - May be too big a tidal volume on this guy so lower the tidal volume which will lower both peak and plateau (switch back to 500)
 - Often we make only 1 change to ventilation and 1 change to oxygen parameters at a time and reassess
- ABG now
 - 7.48/52/125- overventilated, but that's ok, we can make future adjustments

Case based Learning



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Asthma (getting tougher)



- 23 yo M with history of severe asthma on all the usual inhalers presents with acute onset dyspnea and wheezing
- Tried using his albuterol with minimal relief
- PE-
 - healthy looking male in moderate distress
 - Lungs- tachypneic (28), no obvious wheezing
- Blood Gas 7.38/41/72

The normal gas in an asthma attack



**OMINOUS SIGN OF IMPENDING
RESPIRATORY FAILURE**

Intubated



- Placed on CMV 500 RR 16, 50% and PEEP 5
- Patient is breathing about 26 times per minute
- Within 30 minutes, the pressure alarms start sounding
 - Peaks around 50, Plateaus around 40
 - There is a lack of breath sounds bilaterally
 - His BP starts dropping in front of you

Question #2 (not too hard)



- **What do you do in this scenario?**
 - A) Quickly Call RT STAT
 - B) Get a STAT CXR and give him fluids
 - C) Emergent Needle Thoracostomy for his bilateral pneumothoraces
 - D) Increase the Tidal volume because of he is air hungry
 - E) Disconnect the ventilator
 - F) Cower in the corner and call your mommy

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Asthma (and COPD)



- Bronchospasm, airway inflammation, airway edema, and mucus plugging
 - Increase airflow obstruction
 - Decrease expiratory flow
 - Prolong time needed for complete exhalation
- When this expiratory time is insufficient → progressive hyperinflation (dynamic hyperinflation)
- Dynamic hyperinflation creates auto-PEEP

Auto-Peep

- Increases intrathoracic pressure → increases PVR and decreases venous return
 - Net result is decreased cardiac output
 - Culminates into cardiac arrest due to PEA if not treated quickly
- Volume depletion and sedatives can accelerate deterioration
- Treatment usually requires volume resuscitation and alleviating the hyperinflation-usually by disconnecting the vent (allows the patient to exhale)

What minimizes Auto Peep



- **Lower tidal volumes**
 - Less gas to exhale and thus less ability to hyperinflate
- **Decreasing respiratory rate**
 - Increases expiratory time and allows more time for patient to exhale
- **Increasing the inspiratory flow**
 - Shortens inspiratory time thus increasing expiratory time
- **Add low levels of extrinsic PEEP- may reduce efforts to trigger inspiration**
 - Allows less of a gradient if there is intrinsic PEEP that is building up
- **Accepting permissive hypercapnia**
- **Paralysis (so the patient does what you set the ventilator at rather than their own)**

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Next patient



- 49 yo 70 kg male with history of ETOH abuse presents with complaints of abdominal pain
- He has had N/V for 3 days and decreased PO intake
- He complains of diffuse abdominal pain, but worse in the LUQ
- He has mild fevers to 101 and a WBC of 22K
- Lipase is 3000, Amylase is high too (doesn't really matter though)
- Patient dx with pancreatitis and given fluids, narcotics and is NPO

Next 24 hours



- Requires increasing oxygen requirements
- Transferred to ICU
- Conversationally dyspneic and satting 85% on NRB
- CXR done shows bilateral infiltrates
- His weight has remained stable, UOP has remained adequate despite fluids
- Echo is normal except for some tachycardia
- Patient has increased WOB and hypoxia and you intubate him

ARDS-Berlin Definition



- Respiratory Symptoms w/I 1 week of known clinical insult
- Bilateral opacities c/w pulmonary edema
 - Not fully explained by pleural effusions, lobar collapse, lung collapse, or nodules
- Respiratory failure not fully explained by fluid overload
 - Objective assessment is required if no risk for ARDs are present
- Mild/Mod/Severe based on P/F ratio (200/100)

Question # 3



- Which of the following strategies has been shown to have an improved mortality in ARDS
 - A) Tidal volumes of 10-12 cc/kg
 - B) Conservative Fluid Strategy after 24 hours
 - C) IV steroids
 - D) Prone Positioning
 - E) APRV ventilation
 - F) Tidal Volumes of 6 cc/kg or under

Question # 3



- Which of the following strategies has been shown to have an improved mortality in ARDS
 - A) Tidal volumes of 10-12 cc/kg
 - B) Conservative Fluid Strategy after 24 hours
 - C) IV steroids
 - D) Prone Positioning ???- More recent data suggests benefit
 - E) APRV ventilation
 - F) Tidal Volumes of 6 cc/kg or under

Low tidal Volume Ventilation



- **Aka Lung protective ventilation**
 - Smaller tidal volumes are less likely to generate alveolar overdistension
- **ARMA trial**
 - LTVV (6 cc/kg) vs. Conventional MV (12 cc/kg) showed lower mortality rates (31 vs 40%) and more vent free days (12 vs 10)
- **Meta-analysis of 6 RCTs**
 - LTVV improved 28 day mortality (RR 0.74) and hospital mortality (0.80) when compared to conventional MV

LTVV



- Well tolerated in general
- Causes hypercapnic respiratory acidosis
- Goal is to keep $P_{plat} < 30$ to minimize barotrauma in the stiff lungs
- Conventionally this is protocolized in places that perform it

General Method



- Initial TV of 8 cc/kg and RR set to match minute ventilation
- Over next 1-3 hours, TV is reduced to 6 cc/kg
 - Tidal volumes are based on IBW (thus patient weight is not important, it is all based on the height)
 - Formulas to calculate IBW (Devine formula is probably most commonly used)
 - RR can be increased to match minute ventilation



- After reaching 6 cc/kg
 - Subsequent TV adjustments are made on basis of plateau pressures
 - If $P_{plat} > 30$, then TV is decreased by 1 cc/kg to a minimum of 4 cc/kg
 - ✦ I.E: In a 5 ft F, this could be a TV of 180 cc (pretty small huh?)
- Oxygenation goal is PaO_2 of 55-80 or sats 88-95%
- Written protocols outlining Lung protective ventilation is associated with enhanced compliance

Permissive Hypercapnia



- Acceptance of alveolar hypoventilation in order to maintain lower alveolar pressure and minimize overdistension
- Can be minimized by using high RR that doesn't induce autopeep
- Shortening vent tubing and using heated humidifiers decrease hypercapnia by decreasing dead space

PEEP strategies



- **2010 Meta-analysis of 2299 ARDS patients**
 - High peep had lower ICU mortality but no difference in hospital mortality
 - High PEEP did improve oxygenation, increased vent free days, and decreased rescue methods
 - ✦ Subgroup analysis showed the mortality benefit in only the severe ARDS patients and possibly worsened mortality in Mild ARDS
- **2013 Meta-analysis of 2565 ARDS patients**
 - High PEEP was Not associated in benefit
 - Oxygenation did improve in high PEEP group without improvement in vent free days
 - ✦ Subgroup also showed possible decrease ICU mortality in severe ARDs

Pulmonary barotrauma



- Usually manifests as Pneumo(pick your word)
 - Pneumothorax
 - Pneumomediastinum
 - Pneumoperitoneum
 - Subcutaneous emphysema (Pneumofascia??? Anyone?)
- Often requires chest tubes (PTX) or reassurance (all the others)

Other salvage strategies in ARDs



- **Recruitment Maneuvers-** efforts to open collapsed alveoli
 - Usually performed by placing on PEEP 40 for 40 seconds and then going back to previous PEEP setting (+2)
- **Inhaled Pulmonary Vasodilators*****
 - Nitric Oxide, Inhaled Flolan/Veletri- increase oxygenation
- **Prone Positioning*****
 - Recruits alveolar which are in dependent/posterior portions of body and also by “taking the heart off the lungs”
- **Other vent modes (APRV, PCV)**
- **Neuromuscular blockade**
 - Study showed early Cis-atracurium with a mortality benefit
- **ECMO**
 - Specialized centers – came back to the forefront after H1N1

COVID Specific Updates-Based on SCCM



- **Prior to intubation**
 - goal oxygenation should be 92-96%
 - HFNC recommended over Conventional Oxygen
 - Retrospective observational studies
 - ✦ HFNC does NOT appear to confer increased risk of transmission
 - HFNC over NIPPV
 - ✦ In cohort of MERs pts, NIPPV was not associated with improved mortality or LOS
 - ✦ NIPPV was a/w increased Failure rate (92%) and also increased needs for inhaled prostacyclin needs and increased mortality
 - Anecdotal reports of proning on oxygen only
- **Recommend Intubation via RSI**
 - Some institutions are using Intubation Boxes (plexiglass boxes to minimize aerosolization to the surrounding environment)

Covid Specific



- ARDSnet- LTVV, however, often more compliant lungs and thus could start at 8 cc/kg and keep there if doing well
- Patients with Mod/Severe ARDS- highly consider prone positioning 12-16 hrs/day
 - Early use may be beneficial in some patients
- Pulm Vasodilators- trial as rescue therapy, if no response to hypoxia, then quickly taper off
- Recruitment maneuvers are recommended
 - 40 PEEP for 40 seconds over Incremental increases in PEEP
- Steroids**
 - Covid 19 and respiratory failure w/o ARDS- no steroids
 - Covid 19 and respiratory failure w/ ARDS- steroids 1-2 mg/kg/day x 5-7 days could be considered, though SCCM did not come to consensus and has it as a “weak recommendation”
 - Consider steroids if other reasons for steroids (i.e COPD, asthma)
- If intubated and with respiratory failure- recommend empiric Abx until pneumonia other than COVID is ruled out
- Anecdotal information about patients being hypovolemic (due to prolonged fever) and thus gentle hydration may be needed
 - Try to avoid excessive fluid, but also want to avoid diuretics if possible due to AKI needs

Covid and Italy/ESICM recs



- Covid 19 respiratory failure is NOT similar to ARDS
 - Hypoxia is present, but pulmonary compliance is high (not the usual stiff lungs that we see with ARDS)-especially early
 - 2 categories in general
 - ✦ Increased pulmonary compliance with viral pneumonia
 - Hypoxic vasoconstriction, PEEP less helpful and PEEP > 15 more detrimental due to barotrauma/increased intrathoracic pressure (i.e cardiac dysfunction)
 - Patients pretreated with CPAP
 - Increased inspiratory efforts, Vent induced lung injury with lower lung compliance (higher plateaus)
 - Similar to Classic ARDS

Case based Learning



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Last Case



- 49 yo 70 kg F presents with complaints of abdominal pain, dysuria, and polyuria
- This has been worsening over the last several days
- Today, she was found lethargic and was very unsteady on her feet
- In ER her initial BP is 60/40 which transiently responds to Fluid bolus (2L)

PE



- Toxic appearing female in moderate distress
- Card: tachy at 120 (sinus)
- Lungs: tachypneic at about 30, clear lung sounds
- Abdomen: mild diffuse tenderness, soft, no peritoneal signs
- Ext: no c/c/e
- BP drops again and she requires another bolus as well as lines and vasopressors

Labs



- UA is dirty with > 100 WBCs, + leukocyte esterase and nitrites
- Her WBC is 25K, hemoglobin is 12
- BMP shows BUN of 52, creatinine of 3.1, and bicarb of 6
- Lactate returns at 10.3
- CXR is clear

ER physician



- ABG shows 7.12/28/89 on 4L
- Patient with significant respiratory efforts
- Significantly increased WOB, tachypnea
- Intubates patient with RSI
- Asks you to choose initial vent settings

Question 4



- Which of these is the most reasonable initial vent settings?
 - A) CMV TV 400 RR 12 PEEP 5 100% Fio₂
 - B) CMV TV 500 RR 12 PEEP 5 100% Fio₂
 - C) CMV TV 500 RR 18 PEEP 5 50% Fio₂
 - D) CMV TV 700 RR 12 PEEP 10 50% Fio₂
 - E) CMV TV 500 RR 28 PEEP 5 50% Fio₂
 - F) PS 15 PEEP 5 50%

Question 4



- Which of these is the most reasonable initial vent settings?
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 - B) CMV TV 500 RR 12 PEEP 5 100% Fio₂
 - C) CMV TV 500 RR 18 PEEP 5 50% Fio₂
 - D) CMV TV 700 RR 12 PEEP 10 50% Fio₂
 - **E) CMV TV 500 RR 28 PEEP 5 50% Fio₂**
 - F) PS 15 PEEP 5 50%

Common Mistake



- Frequently Minute ventilation is inadequate in patients with significant metabolic acidosis
- Problem is exacerbated by paralysis (especially in patients with RSI)
 - Post intubation ABG is worse (sometimes significantly worse) if inadequate ventilation given
- Patients can “crump” during this time as pressors are less effective in very acidotic environments

Key Points



- **The ABG is your friend**
 - Use it to adjust the vent as needed depending on clinical scenario
- **Tolerate Permissive hypercapnia**
- **Low tidal volume ventilation does have mortality benefits in ARDS**
- **Make sure ventilatory needs are met if metabolic acidosis is occurring**
- **Disconnect the Vent if you must, call for help if needed**
 - RT (though wrong answer on board exam, may be the right answer in real life)
- **Covid specific recommendations as previous stated**
 - Obviously things are changing quickly
 - If disconnecting the vent, this is also considered aerosolizing and should only be done in Airborne isolation situation with appropriate PPE/hospital policy in place

The end

