The Good, The Bad and The Ugly of Neo Volume Targeted Ventilation

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Disclosures

- I do work for Medtronic, which makes the PB980 ventilator. However, this presentation is on a general mode of ventilation. You will see some graphical information from Puritan Bennett ventilators along with others.

Objectives

- Define the benefits of volume targeted ventilation
- Describe the downside of volume targeted ventilation

- UNSYNCHRONIZED PRESSURE CONTROL ONLY

Ventilators Today- provide multiple modes (breath types) of synchronized breathing

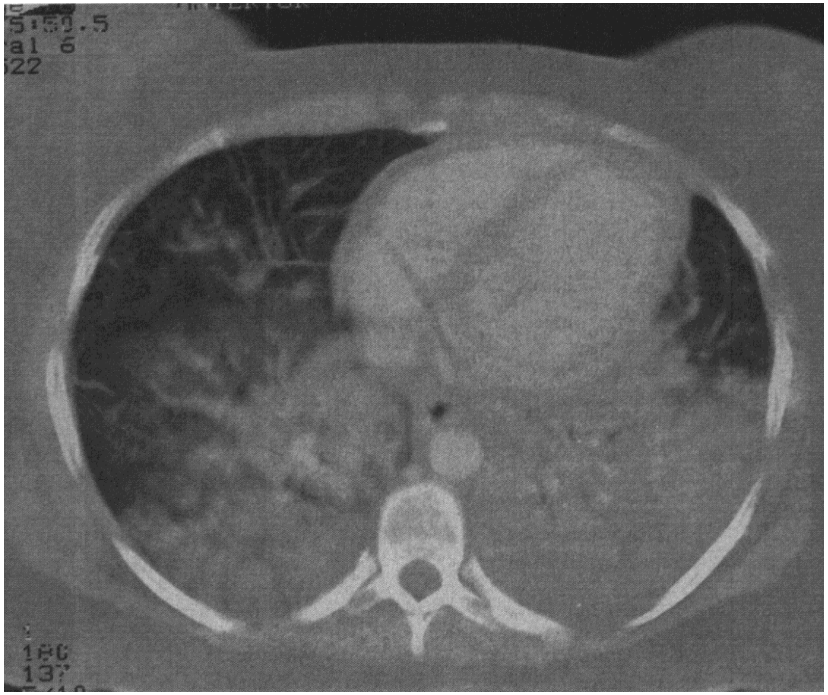
- Pressure Control
- Volume Target
- Pressure Support
- Bilevel/APRV
- As well as Non-invasive modes- CPAP, IMV, SIMV*

- Decrease the work of breathing
- Improve survival rate
- Minimize costs/Decrease time on vent
- Keep driving pressures 15 and under
- Reduce sedation and paralysis
- Improve comfort

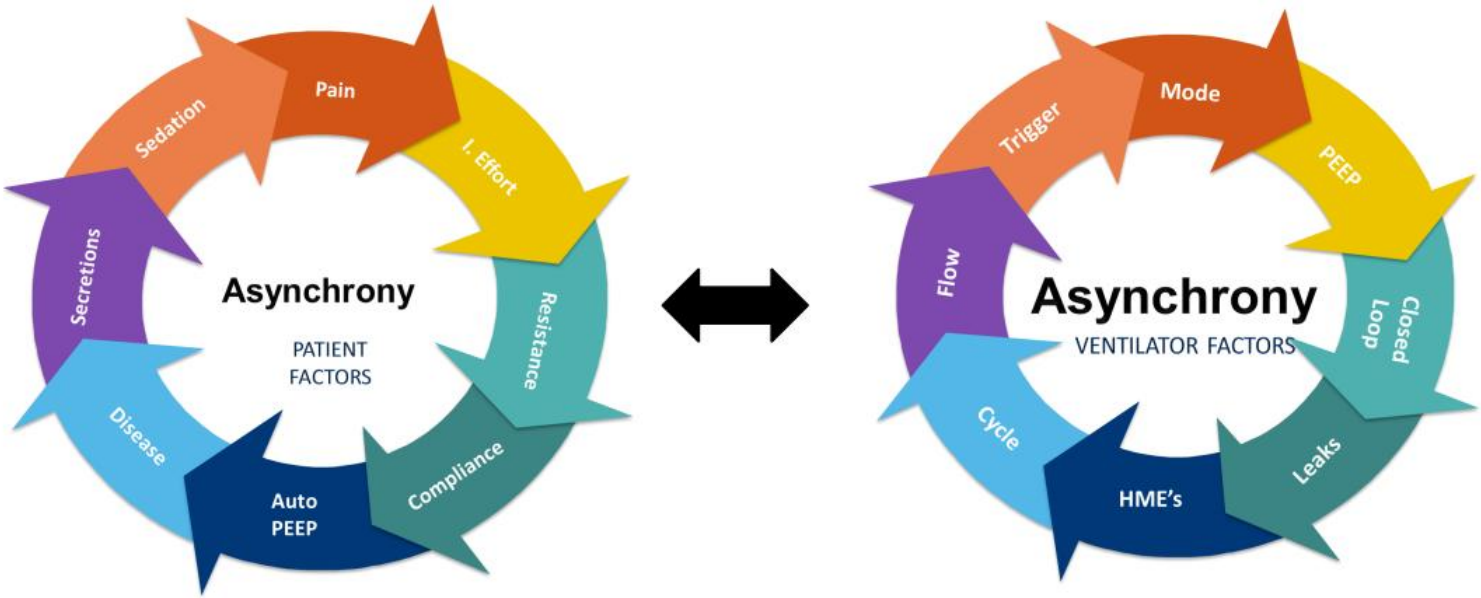
Ventilator-Induced Lung Injury

- Effects of high stretch forces on the lung:
  - Increased capillary permeability
  - Pulmonary edema
  - Alveolar flooding
  - Intrapulmonary hemorrhage

- Results of stretch or “shear” forces:
  - Activation of inflammatory mediators (cytokines)
  - Barotrauma, volutrauma, biotrauma



Complexity of Synchronization in the NICU



Volume Targeted Modes = Adaptive Control

As defined by the AARC, adaptive control is a ventilator targeting scheme in which one variable is automatically adjusted to achieve a predetermined value of another variable.

Adaptive Control is also commonly referred to as Dual Control or Dual Control Breath to Breath ventilation.

Volume Targeted Ventilation

APC was first introduced in the **Servo 300** ventilator in **1991, now most critical care ventilators have a variation of this mode**

- Commercial names for modes that use APC are;[1,2]
- PC/VG
- Autoflow
- Adaptive Pressure Ventilation (APV),
- Pressure Regulated Volume Control (PRVC)
- Volume Support
- Volume Control +
- Volume Target Pressure Control
- Q? are these volume- based breaths or pressure?

Volume Target– How it works

THE VOLUME TARGET VENTILATION STRATEGY ALGORITHM CONSISTS OF AN ADAPTIVE TARGETING SCHEME THAT ADJUSTS THE INSPIRATORY PRESSURE TO DELIVER AT LEAST THE MINIMUM TARGETED TIDAL VOLUME (V_T).[1]

ON INITIATION OF THE MODE THE VENTILATOR PROVIDES A TEST BREATH, WHICH CAN EITHER BE AT A CONSTANT PRESSURE OR VOLUME. THAT TEST BREATH ALLOWS A MEASUREMENT OF THE TOTAL RESPIRATORY-SYSTEM COMPLIANCE. THE ALGORITHM THEN CALCULATES THE REQUIRED PRESSURE TO ACHIEVE THE V_T SET BY THE CLINICIAN. WITH EACH SUBSEQUENT BREATH THE VENTILATOR MEASURES THE PREVIOUS BREATH TO CONTROL OUTPUT “PRESSURE” REQUIRED FOR THE CURRENT BREATH, HENCE THE TERM “DUAL-CONTROL BREATH-TO-BREATH”.[2]

Volume Target- How it works

Pressure on subsequent breaths are either held constant, increased or decreased depending on delivered and targeted V_T. Most ventilator algorithms limit maximum pressure changes breath to breath to 3 cm H_2O.[1]

"Breath-to-breath dual-control modes are analogous to having a respiratory therapist at the bedside increasing or decreasing the pressure limit of each breath based on the V_T of the previous breath."[3]

Dual Modes- VG, PRVC, VC+

Combination or “dual control” modes combine features of pressure and volume targeting to accomplish ventilatory objectives which might remain unmet by either used independently.

AC type dual control mode- all breaths are supported with PC, to target the volume set

Dual modes are pressure based, pressure is different in SIMV

- Spontaneous breaths are **Pressure Support**
- Full support breaths are provided by **Pressure Control**

Volume-targeted versus pressure-limited ventilation in neonates

Klingenberg C, Wheeler KI, McCallion N, Morley CJ, Davis PG.. Cochrane Database of Systematic Reviews 2017, Issue 10. Art. No.: CD003666. DOI: 10.1002/14651858.CD003666.pub4.

- Significantly decreased rate of death or BPD at 36 weeks gestation
- Shorter duration of mechanical ventilation
- Reduced incidence of pneumothorax
- Improved blood gas stability- specifically CO2 which is linked to brain damage.
- Fewer severe brain injuries-grade 3 and 4 IVH.
- No difference in mortality alone.

Volume ventilation in neonates

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PlumX Metrics

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Article Info

Preterm babies are born with immature airways and deficiency of surfactant and a compliant chest wall. This increases the work of breathing with a large proportion of extreme preterm babies requiring invasive ventilation through the endotracheal tube. The improvements in the uptake of antenatal steroids and better perinatal care allow a proportion of these preterm babies to be successfully managed non-invasively. Those ventilated are at risk of iatrogenic lung injury including ventilation induced lung injury. Synchronising the ventilation to the baby's breathing pattern and minimizing lung injury are crucial in reducing complications such as bronchopulmonary dysplasia and long term respiratory morbidity. Volume targeted ventilation in preterm babies has been evaluated in last two decades and is now standard of care. Meta-analysis of trials reports that it improves short-term outcomes to discharge and some complications of prematurity.

Summary

There is convincing evidence to support use of volume-targeted modes of ventilation as it has been reported to reduce the incidence of chronic lung disease in preterm babies. There are varieties of modalities available within the volume-targeted ventilation. Volume guarantee ventilation has been widely used in recent times across Neonatal Intensive care units. There are however a number of unanswered questions including what should be the tidal volume set on the ventilator (range is 4–8 ml/kg) and how should the babies weaned on the ventilation. The best method of synchronization is also debated as the current generation of ventilators use flow with the exception of one ventilator that uses diaphragmatic activity. This needs further research into evaluating VTV and the impact on neurodevelopment and respiratory outcomes.

Advantages of Volume Targeted Ventilation

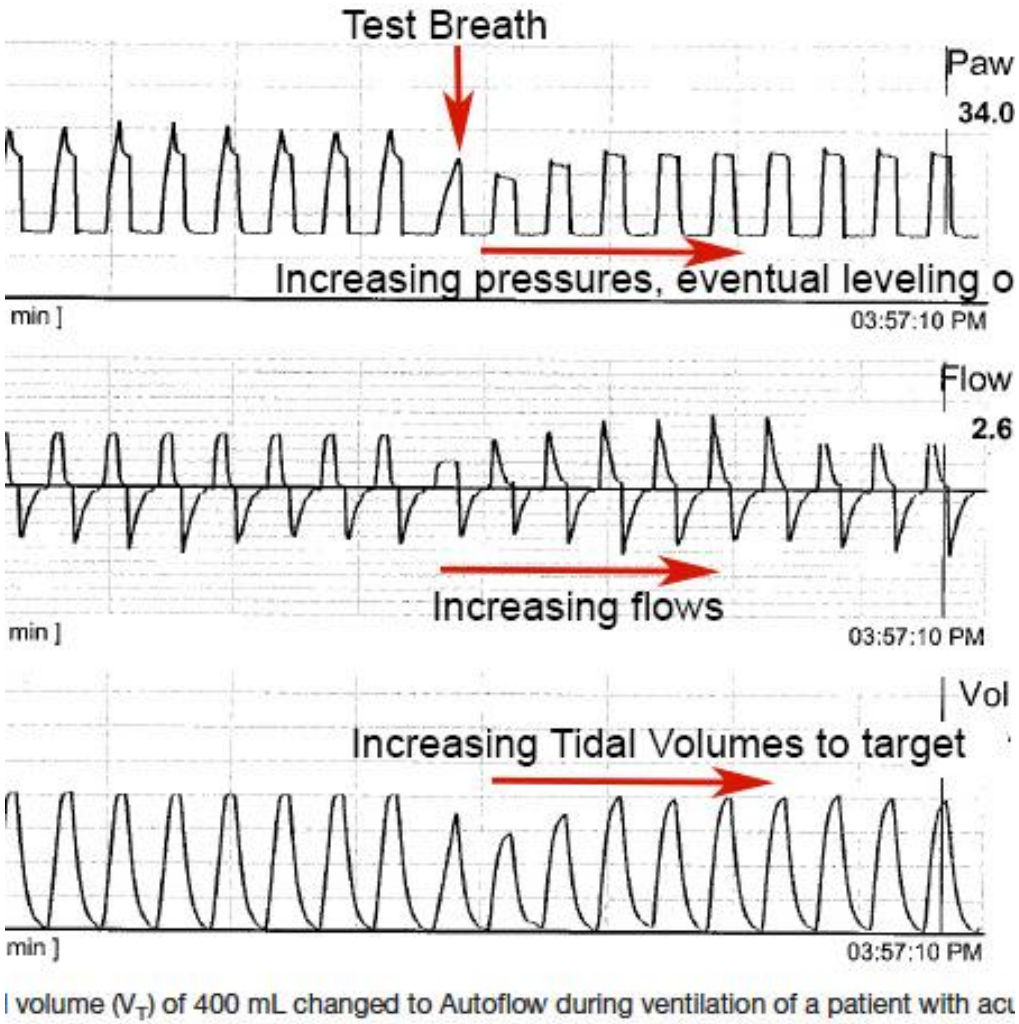
Delivers targeted V_T at lowest airway pressures

Automatically compensates for changes in patient conditions/compliance

Better Patient-Ventilatory Synchrony compared to Volume Control

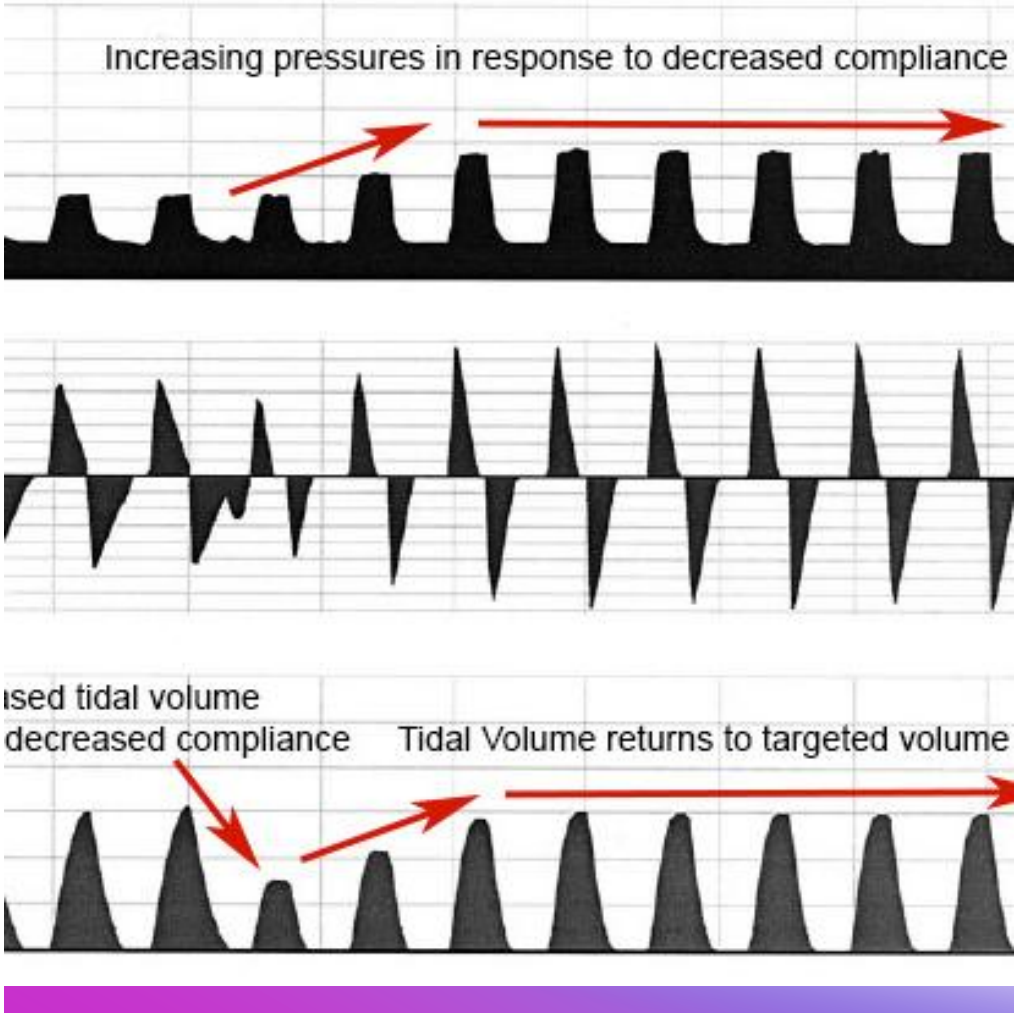
Less Clinician Intervention

"Automated Weaning"- What does this mean to you?



Targeted V_T at lower pressures

- Branson RD, Johannigman JA; The Role of Ventilator Graphics When Setting Dual-Control Modes. . RESPIRATORY CARE • FEBRUARY 2005 VOL 50 NO 2

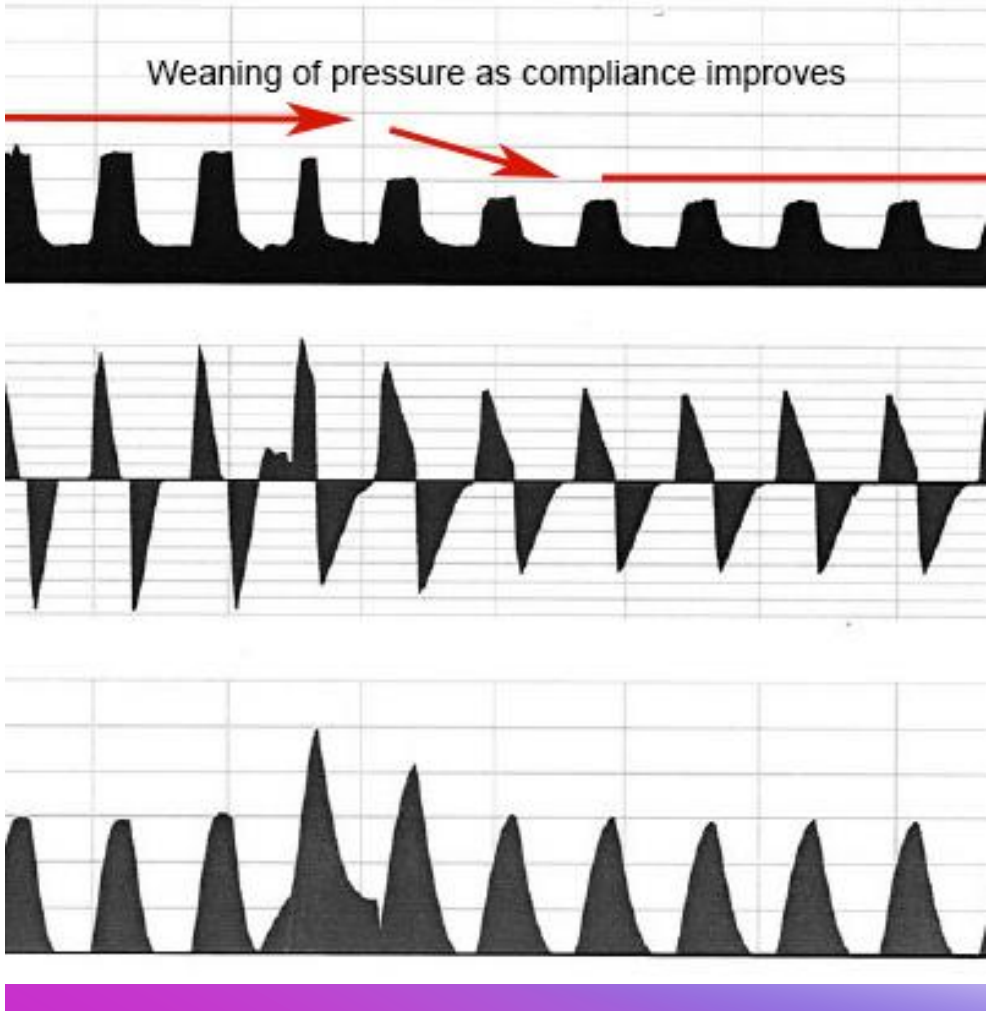


Decreasing compliance

- Branson RD, Johannigman JA; The Role of Ventilator Graphics When Setting Dual-Control Modes. . RESPIRATORY CARE • FEBRUARY 2005 VOL 50 NO 2

Automatic weaning of support

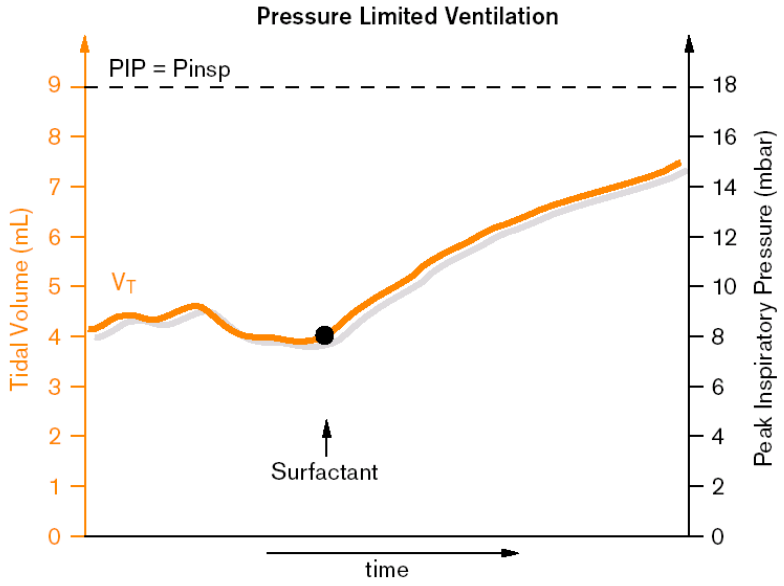
- Branson RD, Johannigman JA; The Role of Ventilator Graphics When Setting Dual-Control Modes. . RESPIRATORY CARE • FEBRUARY 2005 VOL 50 NO 2

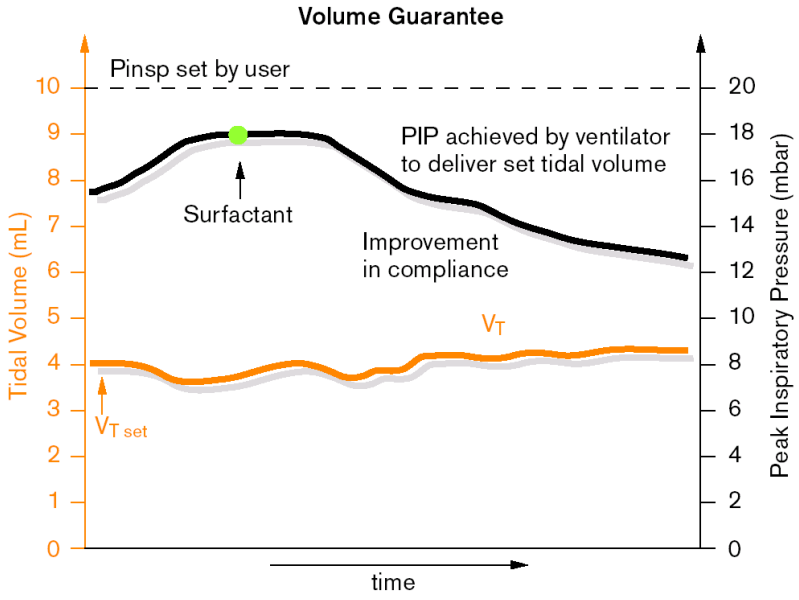


How much does pressure change?

Condition	PBW < 3.5	3.5 ≥ PBW < 7	7 ≥ PBW < 15	15 ≥ PBW < 20	20 ≥ PBW
Maximum Pressure Increase Adjustment Per Breath (cmH_2O)	+3	+4.5	+6	+8	+10
Maximum Pressure Decrease Adjustment Per Breath (cmH_2O)	−6	−6	−6	−8	−10

Surfactant Delivery



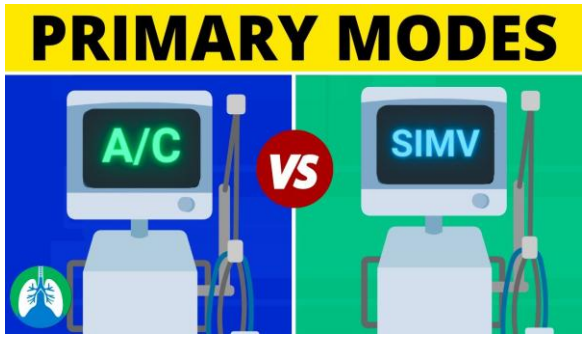


AC or SIMV in Volume Targeted

- SIMV- breath types (PS vs VT) differ in how they "move" with changes in infant's compliance and effort

  - Kezler et al. (2005), detailed infants on SIMV vs AC/volume targeted **had increased WOB, HR and RR with lower SPO2**

  - **More consistent tidal volumes at lower total respiratory rates with AC** than SIMV
    (Mrozek et al., 2008)



-- Batra et al. (2023) Meta review of seven publications.
AC was associated with shorter weaning duration, however no difference in BPD rate.

Disadvantages of VT Targeted

Varied delivery of V_T's in spontaneously breathing patients with variable degrees of effort, rates and patterns

Can contribute to auto-peep

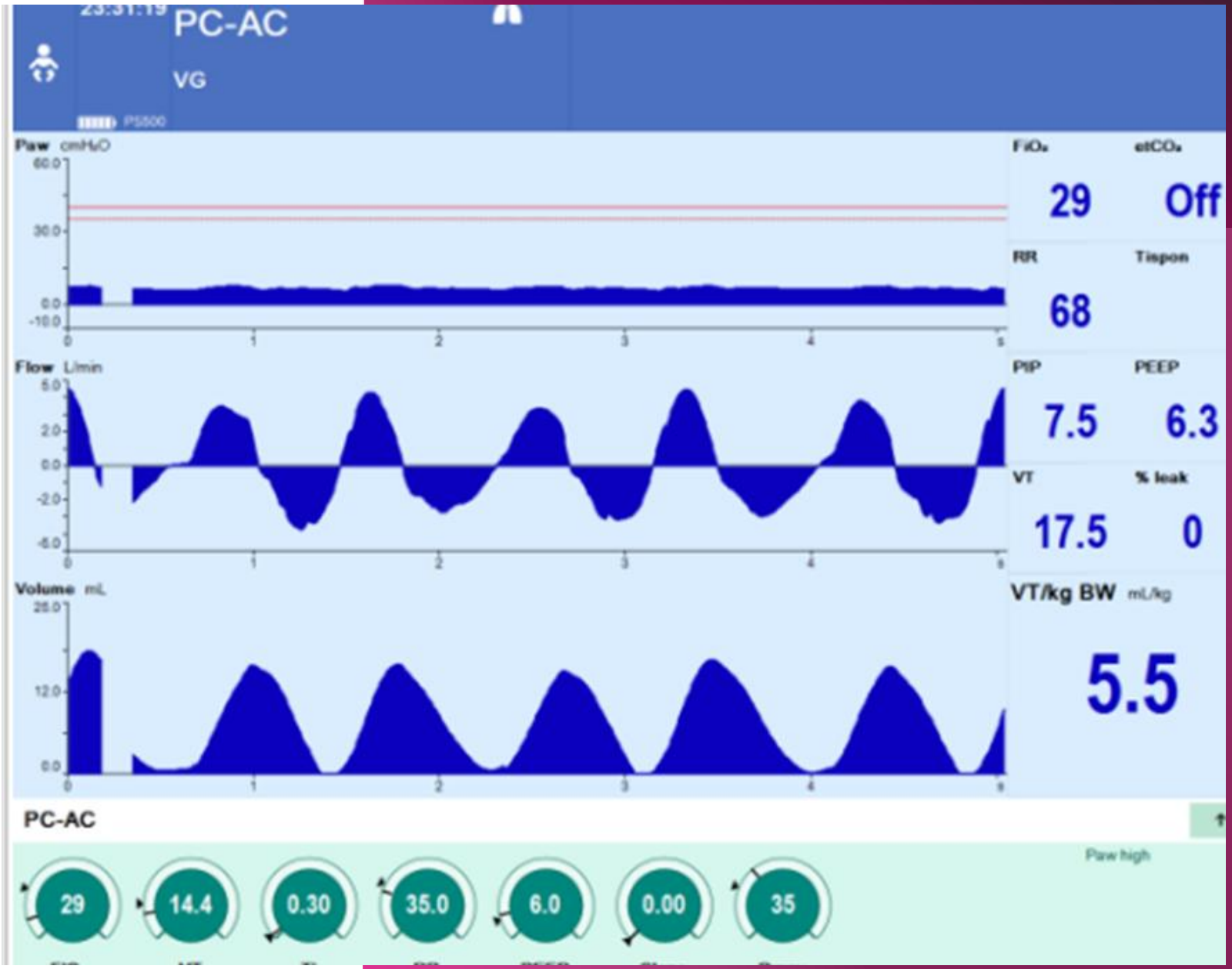
Cannot distinguish between improving lung mechanics and increased patient demand or effort, thus inappropriately decreasing support in patients who may need it.

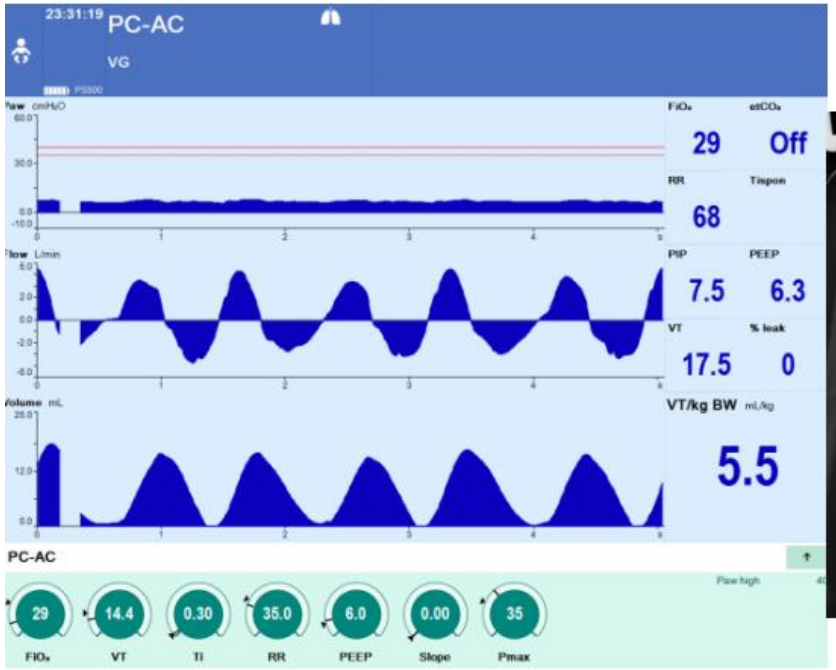
Not always good weaning mode for patients in SIMV/Volume Targeted with good effort

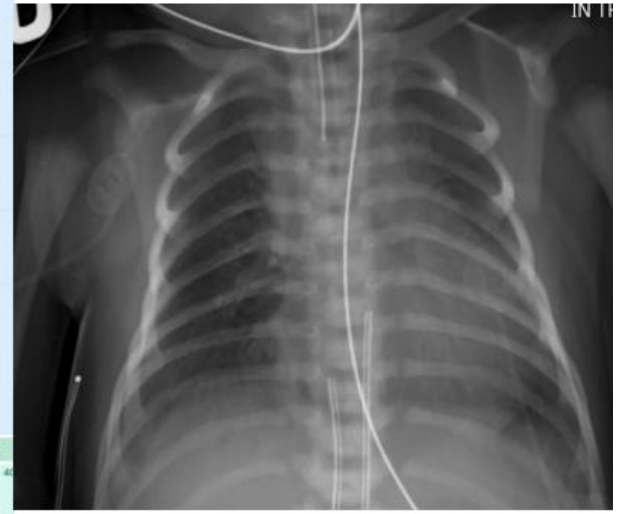
Nursing care and pressures

Dual Mode Pitfalls

The machine doesn't know the difference between a patient who is providing more effort because he's getting better compared to a patient who is providing more effort because he's getting sicker!


PC-AC
VG
Paw cmH2O
60.0
30.0
0.0
-10.0
Flow L/min
5.0
2.0
0.0
-2.0
-6.0
Volume mL
25.0
12.0
0.0
FiO2
29
etCO2
Off
RR
68
Tispon
PIP
7.5
PEEP
6.3
VT
17.5
% leak
0
VT/kg BW mL/kg
5.5
PC-AC
Paw high
29
14.4
0.30
35.0
6.0
0.00
35



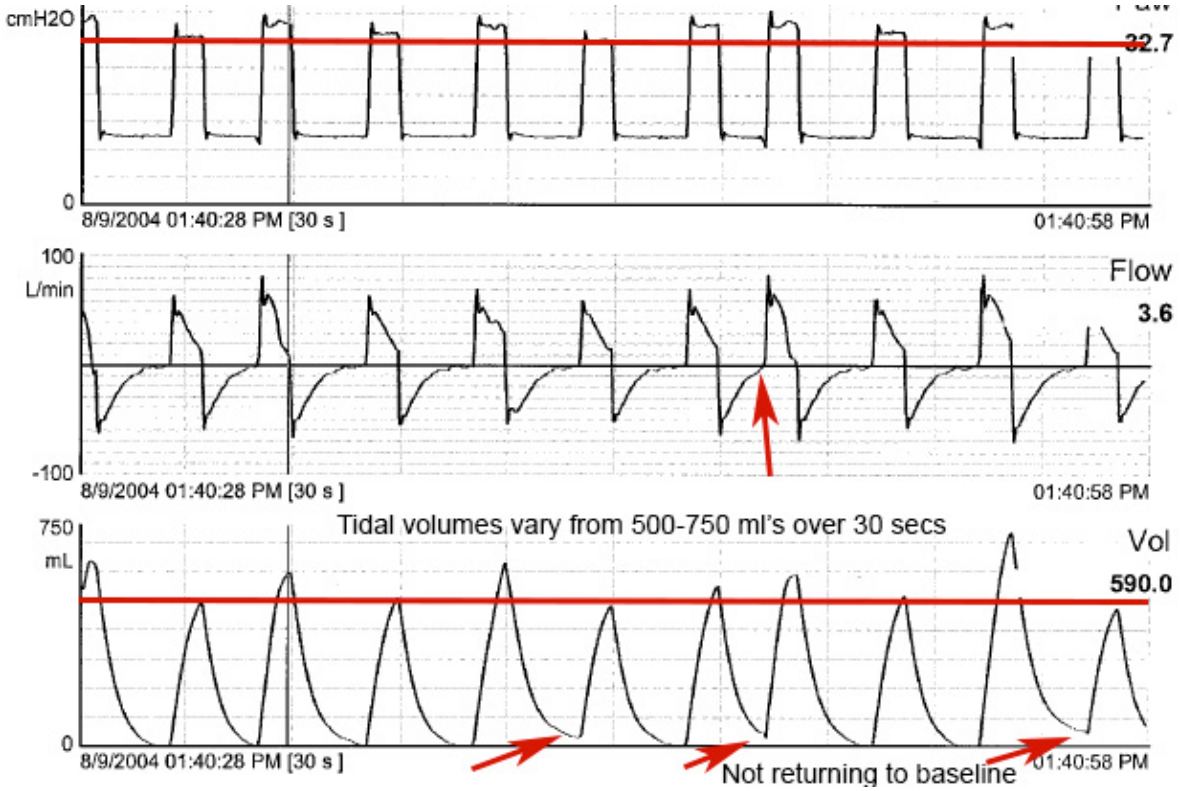


Airway graphics revealed consistently low PIP values with spont. V_T greater than that set on the ventilator. The chest x-ray showed low lung volumes with increasing atelectasis and air bronchograms from the previous exam. The patient developed retractions, nasal flaring, and SpO2 85-89% Breath sounds were reduced in the bases with fine inspiratory crackles throughout.

What can you do?

In situations where the patient is getting inconsistent V_T's or inspiratory demand is not being met consider:

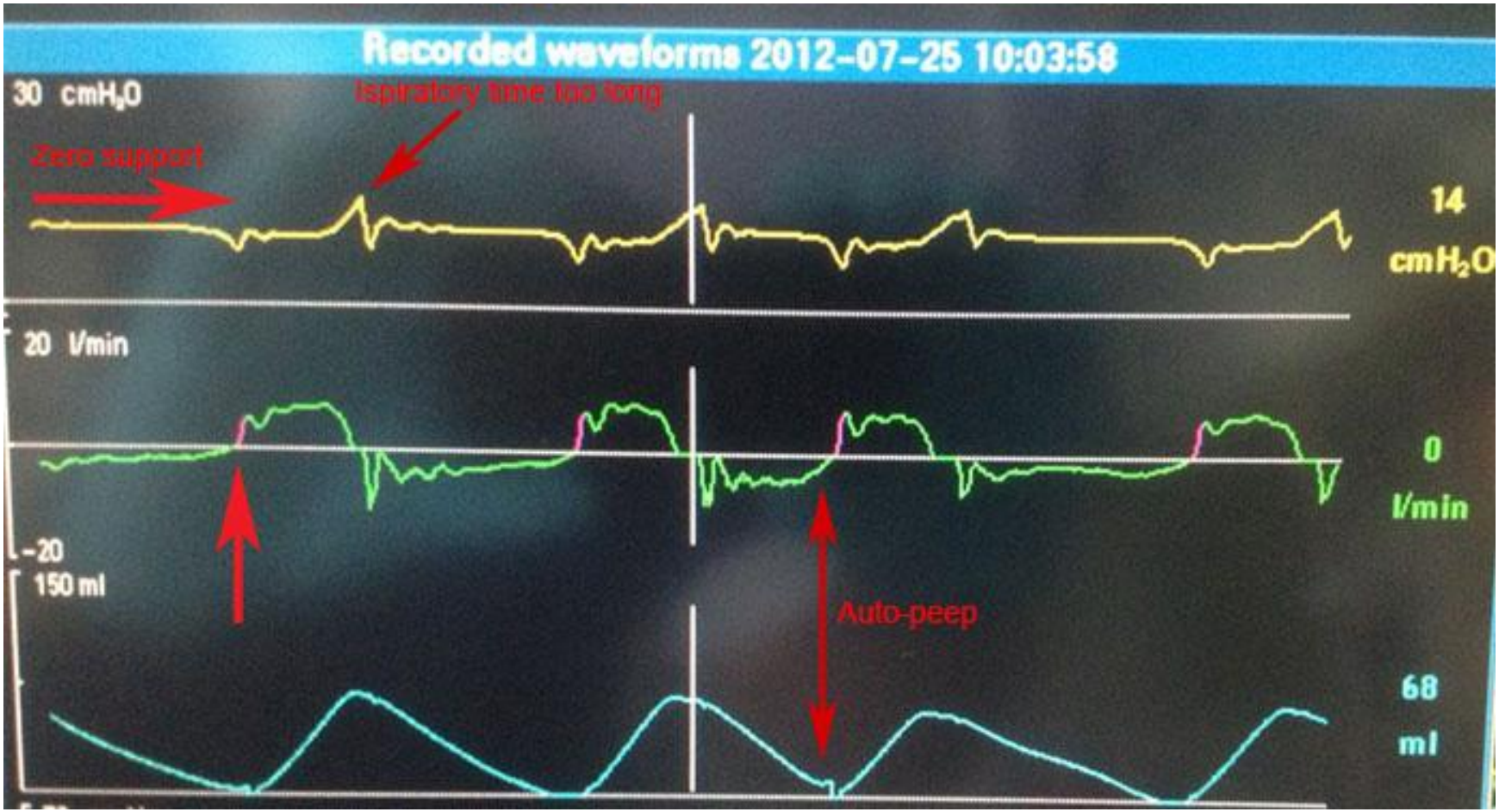
- Switching patient to PC – this will allow sufficient inspiratory support while maintaining a set pressure but with varying volumes
- Evaluating whether sedation is warranted – sedating patient may allow more consistent volumes, must weigh risk/benefits
- Increasing V_T to match patient demands – meeting patient demands will help to ensure proper ventilator support but attempting to maintain a lung protective strategy with small tidal volumes may prove difficult if patient is demanding large volumes

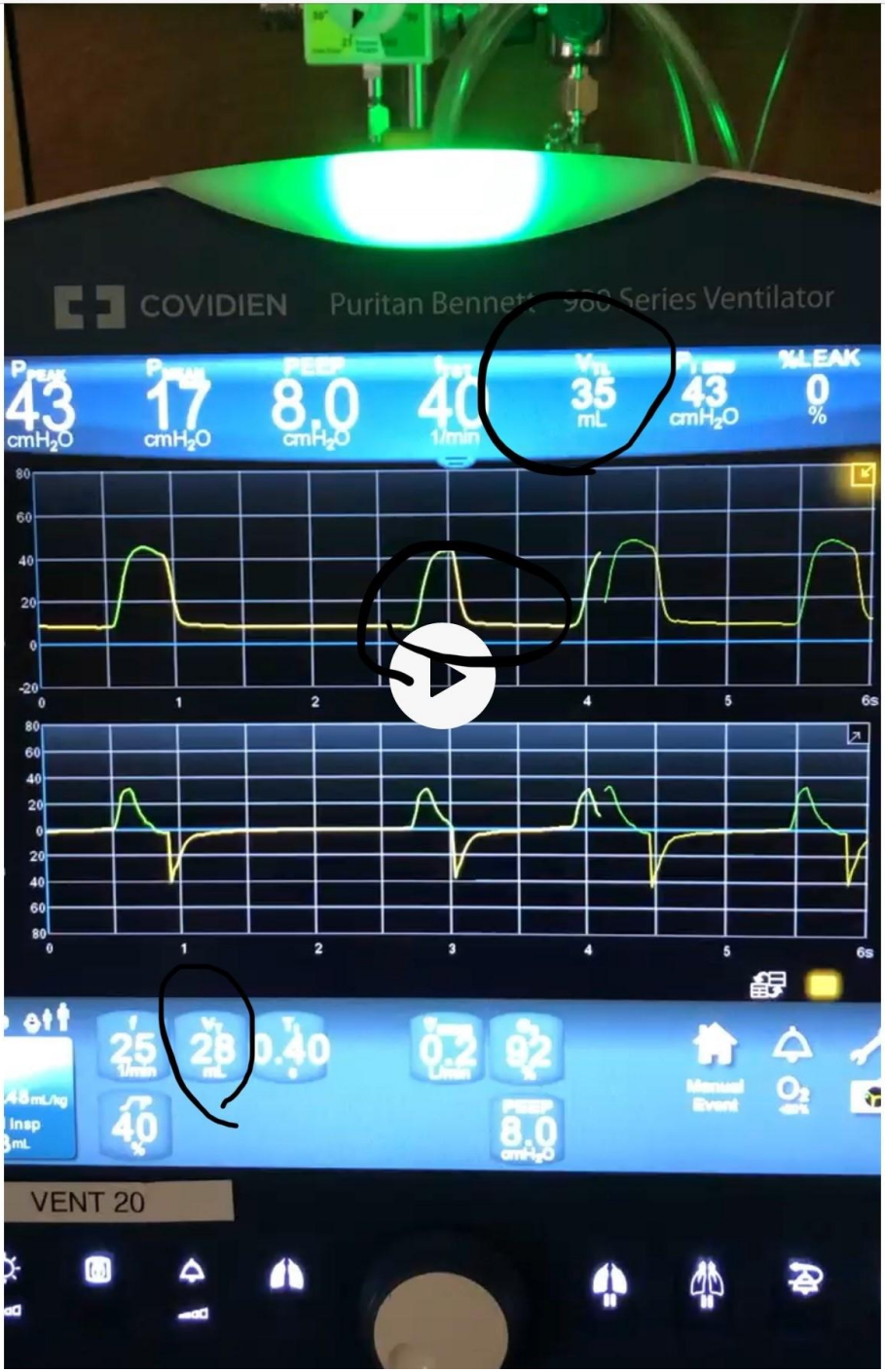


Intrinsic positive end-expiratory pressure (auto-peep)

- Branson RD, Johannigman JA; The Role of Ventilator Graphics When Setting Dual-Control Modes. . RESPIRATORY CARE • FEBRUARY 2005 VOL 50 NO 2

Real patient example



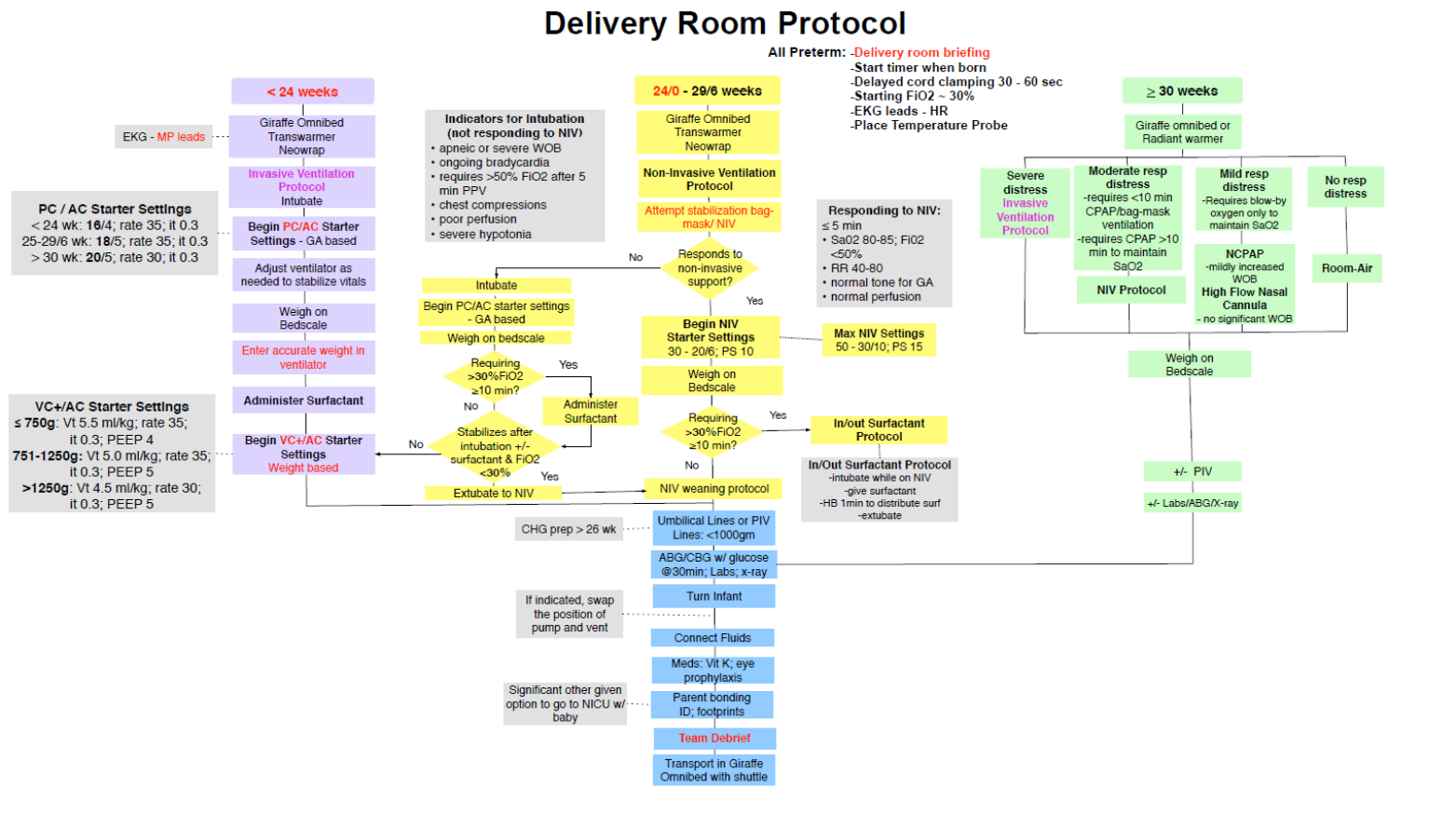

COVIDIEN
Puritan Bennett 980 Series Ventilator
PEAK 43 cmH2O
PMEAN 17 cmH2O
PEEP 8.0 cmH2O
f TOT 40 1/min
VTE 35 mL
PI MAX 43 cmH2O
%LEAK 0 %
80
60
40
20
0
-20
0 1 2 4 5 6s
80
60
40
20
0
20
40
60
80
0 1 2 3 4 5 6s
25 1/min
28 mL
0.40
0.2 L/min
92 %
40 %
PEEP 8.0 cmH2O
Manual Event
VENT 20

Weaning issues

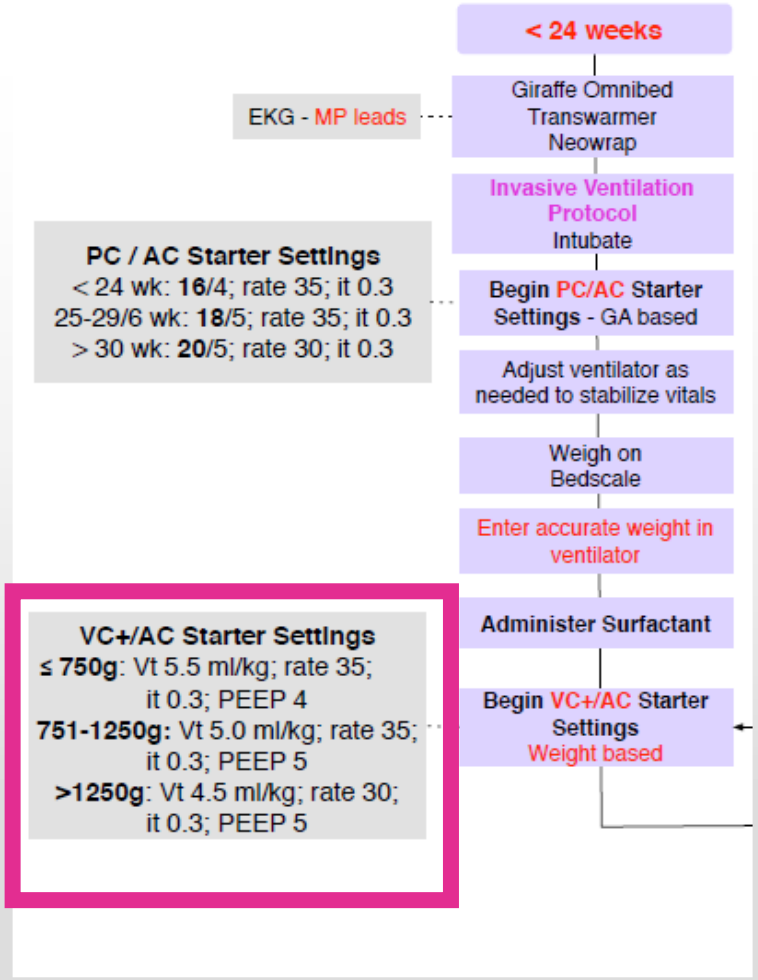
If patient is in Volume Target and effort is high, reduced support may unnecessarily tire patient because of increased load placed on patient.

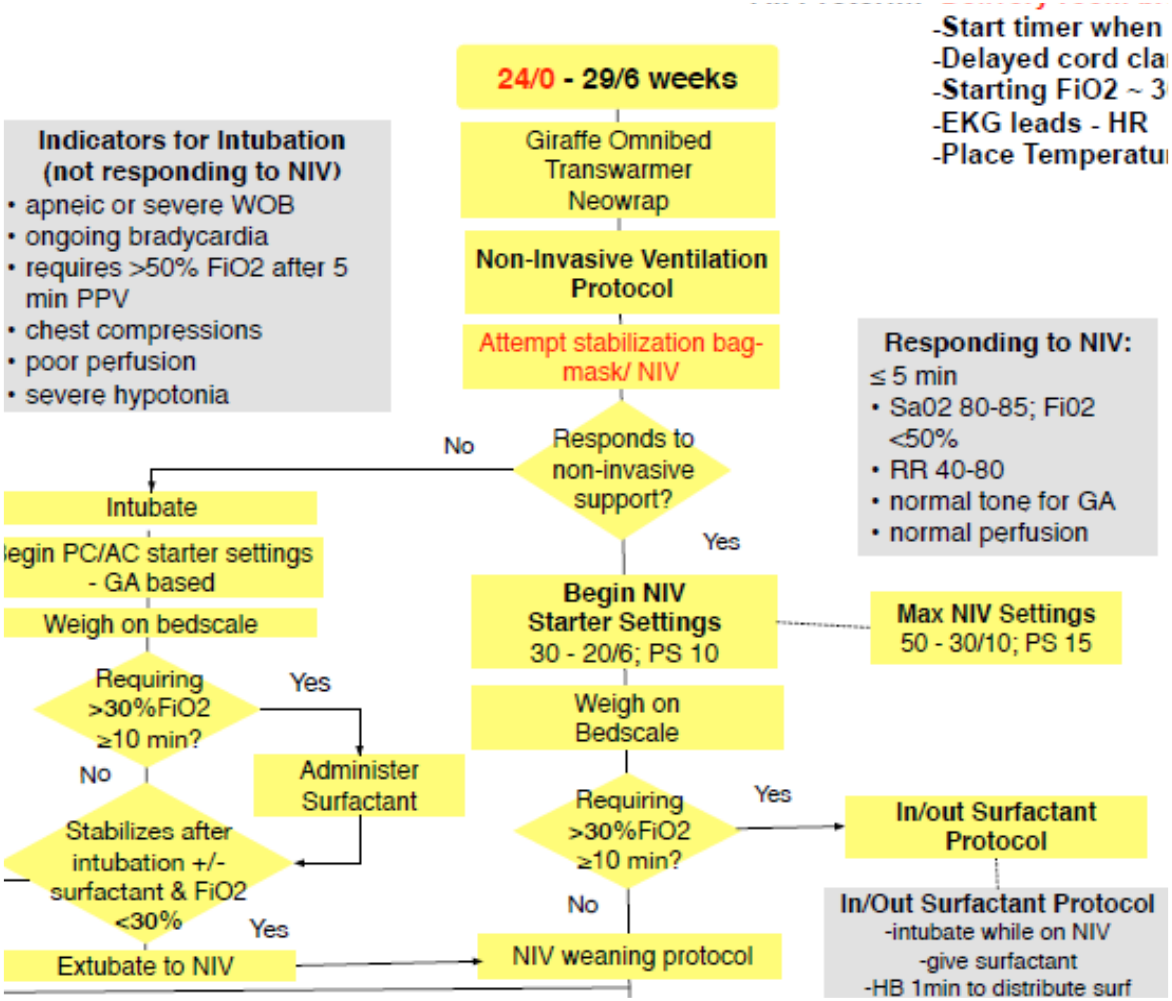
If patient is in SIMV/volume target and effort is high, PS breaths may be higher or more supported than volume target breaths. In this situation weaning of the control rate will inadvertently increase support due to increased PS breaths.


COVIDIEN
Puritan Bennett 980 Series Ventilator
P PEAK 10 cmH2O
P MEAN 10 cmH2O
f TOT 33 1/min
V TI 123 mL
V E TOT 3.72 L/min
EEF 0.0 L/min
V TI/PBW 6.2 mL/kg
PEEP 6.9 cmH2O
P CIRC cmH2O
INSP
V CIRC L/min EXP
Menu
Adult
SIMV
f 16 1/min
VT 1200 mL
TI 0.65 s
P SUPP 10 cmH2O
V SENS 0.7 L/min
O2 21 %
Manual
O2



- Credit to Woman's Hospital, Baton Rouge, La


< 24 weeks
Giraffe Omnibed
Transwarmer
Neowrap
EKG - MP leads
Invasive Ventilation Protocol
Intubate
PC / AC Starter Settings
< 24 wk: 16/4; rate 35; it 0.3
25-29/6 wk: 18/5; rate 35; it 0.3
> 30 wk: 20/5; rate 30; it 0.3
Begin PC/AC Starter Settings - GA based
Adjust ventilator as needed to stabilize vitals
Weigh on Bedscale
Enter accurate weight in ventilator
VC+/AC Starter Settings
≤ 750g: Vt 5.5 ml/kg; rate 35; it 0.3; PEEP 4
751-1250g: Vt 5.0 ml/kg; rate 35; it 0.3; PEEP 5
>1250g: Vt 4.5 ml/kg; rate 30; it 0.3; PEEP 5
Administer Surfactant
Begin VC+/AC Starter Settings
Weight based


-Start timer when
-Delayed cord cla
-Starting FiO2 ~ 3
-EKG leads - HR
-Place Temperatu
24/0 - 29/6 weeks
Giraffe Omnibed
Transwarmer
Neowrap
Non-Invasive Ventilation Protocol
Attempt stabilization bag-mask/ NIV
Indicators for Intubation (not responding to NIV)
• apneic or severe WOB
• ongoing bradycardia
• requires >50% FiO2 after 5 min PPV
• chest compressions
• poor perfusion
• severe hypotonia
Responds to non-invasive support?
No
Yes
Responding to NIV:
≤ 5 min
• Sa02 80-85; Fi02 <50%
• RR 40-80
• normal tone for GA
• normal perfusion
Intubate
egin PC/AC starter settings - GA based
Weigh on bedscale
Begin NIV Starter Settings
30 - 20/6; PS 10
Max NIV Settings
50 - 30/10; PS 15
Requiring >30%FiO2 ≥10 min?
Yes
No
Administer Surfactant
Weigh on Bedscale
Stabilizes after intubation +/- surfactant & FiO2 <30%
Requiring >30%FiO2 ≥10 min?
Yes
No
In/out Surfactant Protocol
In/Out Surfactant Protocol
-intubate while on NIV
-give surfactant
-HB 1min to distribute surf
Yes
Extubate to NIV
NIV weaning protocol

Seattle Children's Protocol

- **Shared with permission from SCH**

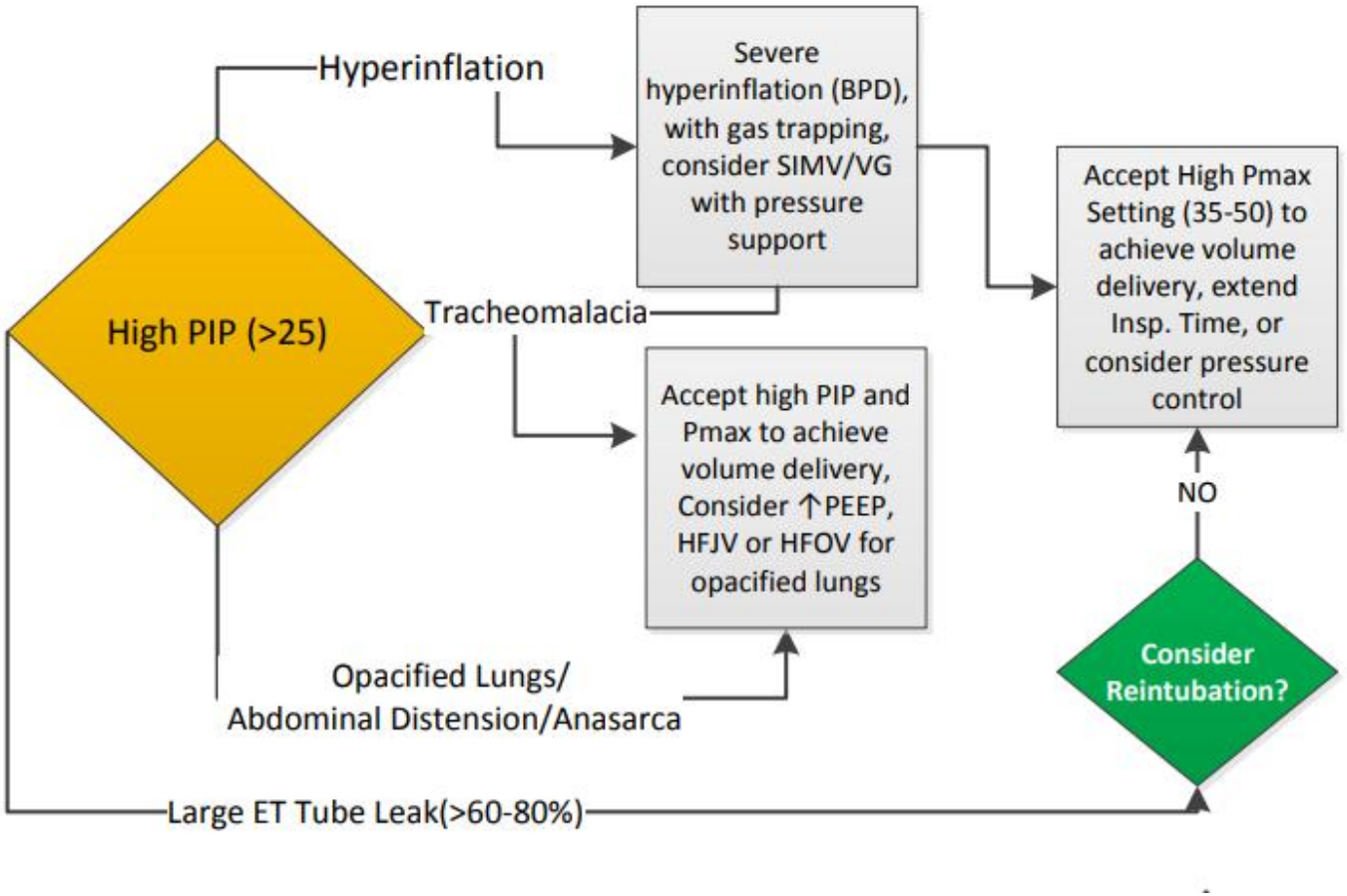
All babies started on AC, Volume Targeted Mode

- VC+
- VG
- PRVC

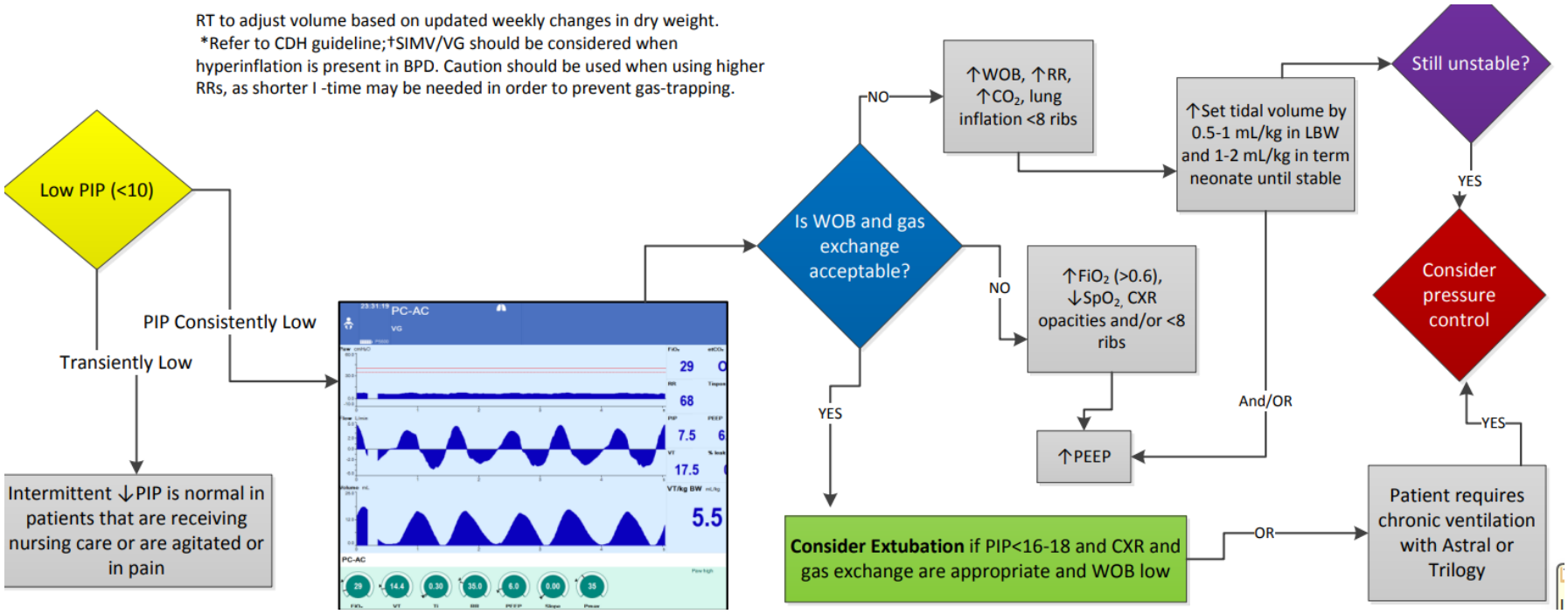
Weight - Age	Tidal volume (mL/kg)	PEEP (cmH_2O)	Rate	I Time (s)
At Birth				
< 1.0 kg	4-6	5-7	40-60	0.25-0.3
1.0-1.5 kg	5-6	5-8	40	0.3-0.35
> 1.5 kg	6-7	5-8	40	0.3-0.4
CDH*	4-5	5-6	40-60	0.3–0.4
At > 2 wks on ventilator†	Consider increase V_T by 0.5 – 1.5 mL/kg	5-8	20-40	0.35-0.45
BPD – moderate (> 4 wks)†	6-8	6-10	20-40	0.35 - 0.45
BPD – severe (> 4 wks)†	7-10	7-10	20-30	0.4 -0.6

RT to adjust volume based on updated weekly changes in dry weight.
*Refer to CDH guideline;†SIMV/VG should be considered when hyperinflation is present in BPD. Caution should be used when using higher RRs, as shorter I -time may be needed in order to prevent gas-trapping.

High Pip Arm SCH protocol



Low PIP Arm SCH Protocol



Summary

In most patient populations Volume Target functions as advertised, delivering targeted V_T's while adjusting pressures in accordance with the patients respiratory-system compliance.

While advanced modes of ventilation such as volume target aim to reduce the workload and monitoring of mechanically ventilated patients, the need for knowledgeable clinicians who can assess the need for the appropriate application and interventions is still invaluable!

Questions?

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