Patient – Ventilator Asynchrony: Causes, Solutions and New Modes of Ventilation!

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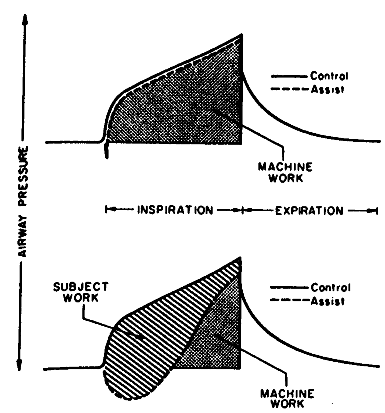
Potential Conflicts of Interest

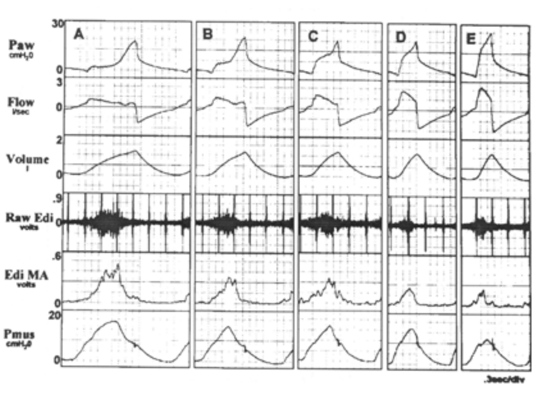
- Received research grants from Hamilton, Covidien and General Electric
- Received honorarium for lecturing from Covidien
- Consultant for Newport



Marini ARRD 1986;134:902

Inspiratory Time

- In spontaneous breathing patients, ventilator inspiratory time should equal patient desired inspiratory time.
- Spontaneous breathing - inspiratory time $\leq$ 1.0 seconds.
- Patients with high ventilatory demand, inspiratory time maybe as short as 0.5 seconds.



Fernandez AJRCCM 1999;159:710

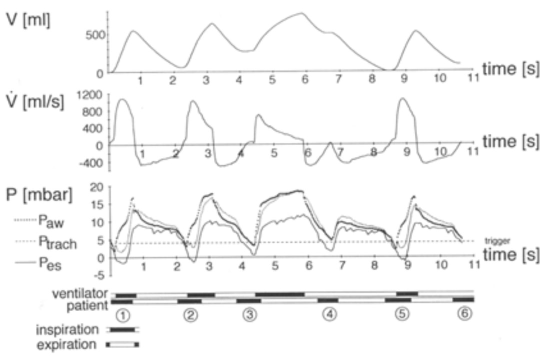
Pressure targeted ventilation better able to match patient demand than volume ventilation, patient-ventilator synchrony enhanced with pressure ventilation

Pressure vs Volume Ventilation

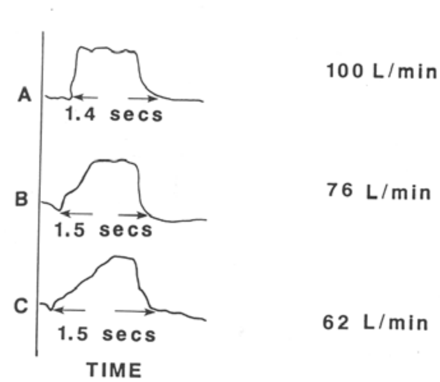
	Pressure	**Volume**
Tidal Volume	Variable	Constant
Peak Alv Press	Constant	Variable
Peak Air Press	Constant	Variable
Flow Pattern	Decelerating	Preset
Peak Flow	Variable	Constant
Inspir Time	Preset	Preset
Minimum Rate	Preset	Preset

Pressure Support

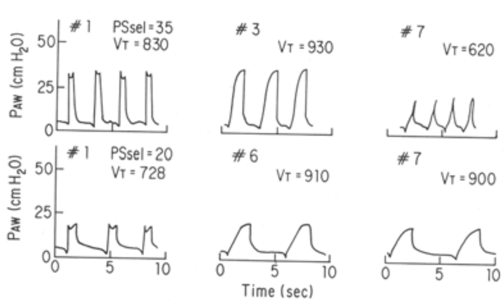
- Provides little control over ventilation
- Only factor controlled is peak pressure
- Useful during initial support or following the most acute stage of ventilatory support
- Commonly used mode of ventilation



Fabry Chest 1995:107:1387



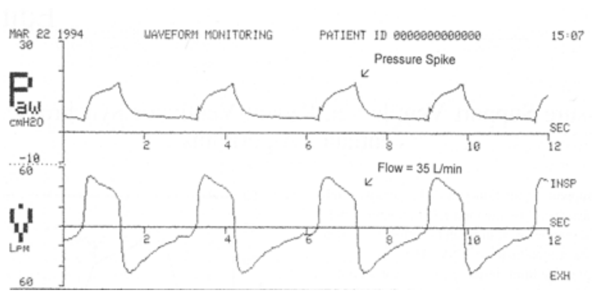
Branson RC 1990;35:1056



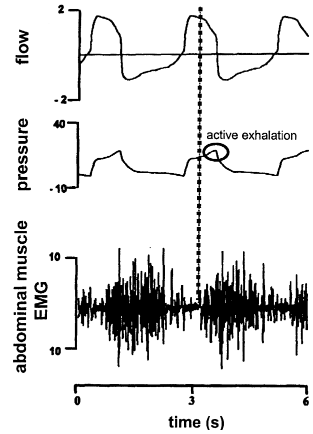
MacIntyre Chest 1991:99:134

Rise Time

- Can be adjusted on all pressure targeted modes of ventiation
- Initial Pressure should not exceed set level
- No Delay in Initial Increase in Pressure
- Initial Pressure Rise should not be Concave
- If Ventilator does not have Rise Time, consider **cautiously** increasing pressure
- The future – ventilators will automatically adjust rise time



Branson, Campbell RC 1998;43:1045



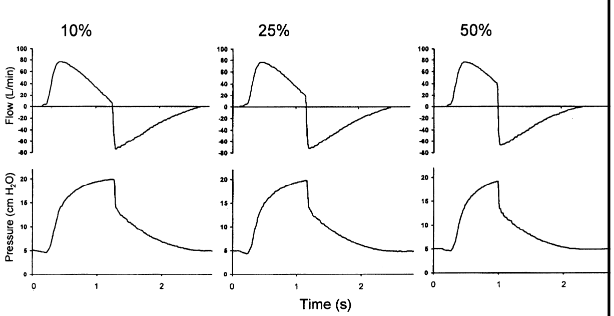
Parthasarathy AJRCCM 1998;159:1023

PSV: Termination of Inspiration

- Primary method: Patients Inspiratory Flow Decreases to a Predetermined Level
  - % of Peak Inspiratory Flow, Usually 25%
    - Some low flow 5 LPM or
    - 5% of Peak Flow
  - Other newer ventilators Variable termination criteria
    - From 5% to 85%

PSV: Termination of Inspiration

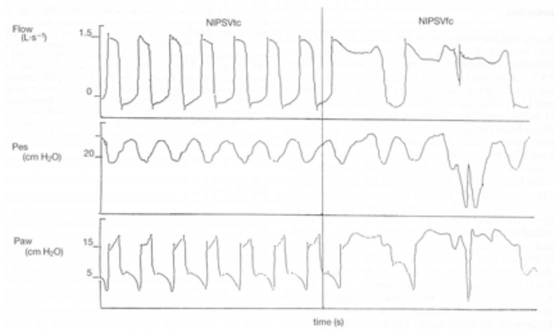
- Secondary Termination Criteria: End Inspiratory Pressure exceeds Target Level
- Tertiary Termination Criteria: Lengthy Inspiratory Time (2 to 3 Sec)



Hess RC 2005:50:166

Inspiratory Termination Criteria

- Adjust termination criteria (PSV) or inspiratory time (PA/C) to avoid a spike in pressure at end exhalation and to avoid premature ending of the breath
- 20 to 25 % inspiratory termination criteria usually appropriate for most Patients
- The future - ventilators will automatically adjust termination criteria to meet changing demand



Calderini ICM 1999;25:662

PS vs. PA/C

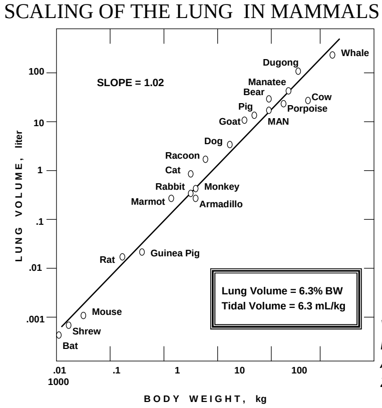
	PS	PA/C
Pressure level	Set	Set
Inspiratory Time	Pt controlled	Set
Rate	Pt controlled	Back up Set

Gas Delivery Pattern the Same for both Modes

Inappropriate PSV or PA/C Level

- To low a pressure level increases patient demand increasing patient work
- To high a level causes dysynchrony: forced exhalation , air trapping and increased ventilatory demand
- Frequently, decreasing PSV or PA/C level may be the correct choice

SCALING OF THE LUNG IN MAMMALS



Villar, Kacmarek, Hedenstierna. Acta Anaesth Scand 2004; 48:267-271.

Adapted from SM Tenney & JE Remmers, Nature 1963; 197:54-6, K Schmidt-Nielsen, Science 1972

Proportional Assist Ventilation

- PAV based on the equation of motion
- Increases or decreases ventilatory support in proportion to patient effort
- Similar in concept to **Power Steering**
- Tracks changes in patient effort and adjusts ventilator output to reduce work
- Introduced by Younes in 1992

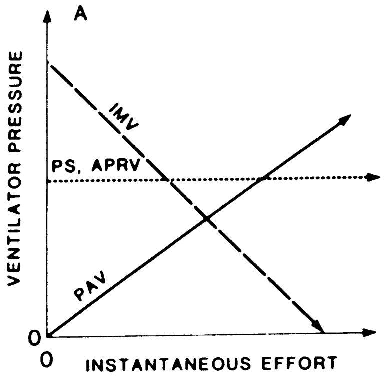
(Younes M, ARRD 1992;145:121)

Equation of Motion for the respiratory system

Ventilator output : Triggering, Cycling
Control of flow, rise time and pressure

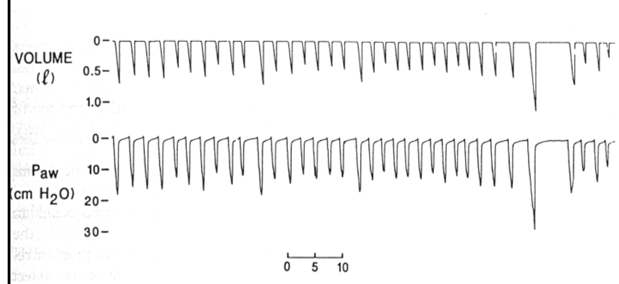
$$Paw + Pmus = V' \times R + \Delta V \times E$$

Patient response
Mechanical
Chemical
Reflex
Behavioral



Younes ARRD 1992;145:114

PAV



Younes M. AARD 1992;145:121

Proposed Advantages of PAV

- –Changing ventilator output to meet patient demand
- –Variable volume
- –Improved synchrony
- –Reduced missed triggers
- –Adapts to patient neural control

Limitations of PAV

- Difficulty measuring elastance and resistance on-line breath to breath
- Treating the lung as if elastance and resistance are linear
- Intact ventilatory drive required
- Leaks

PAV versus PSV

- PAV preserved the ability of patients to modulate V_T in response to hypercapnia
- Changes in V_E during PSV results in changes in respiratory frequency
- Increasing V_E during PSV results in greater muscle effort and greater patient discomfort than PAV
  - Ranieri JAP 1996;81:426
  - Grasso AJRCCM 2000;161:819
  - Kondili ICM 2006;32:692

Gay AJRCCM 2001;164:1606

- RCT non-invasive PAV (n=21) vs. non-invasive PSV (n=23) in COPD patients in an acute exacerbation.
- Mortality and intubation rates similar
- PAV respiratory rate decreased to a greater extent , p = 0.02
- PCO_2 decreased faster with PAV, p <0.05
- Mask comfort better with PAV, p <0.05
- PSV a greater number of patients refused Rx, p < 0.01

Rusterholtz ICM 2008;34:840

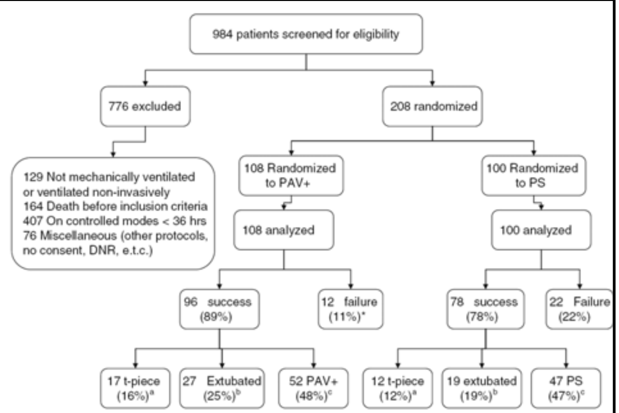
- RCT - CPAP vs PAV during NIV in patients in acute cardiogenic pulmonary edema
- 3 centers, 36 patients
- CPAP at 10 cmH_2O, PAV at maximum assist, just below runaway PAV level
- No differences in physiologic variables
- 7 patients failed CPAP with 4 requiring intubation
- 7 patients failed PAV with 5 requiring intubation

Kondili Anes 2006;105:703

- PAV vs. PSV in 12 patients with ALI/ARDS due to sepsis, P/F 190 ± 49 mmHg
- 30 min in random order mean airway pressure constant
- PAV - RR higher 24.5+6.9 vs. 21.4+6.9, $p < 0.05$
- PAV - VT lower 7.7+1.9 vs. 8.0+1.6 ml/Kg but not significantly
- PAV - CI higher 4.4+1.6 vs. 4.1+1.3 L/min/m^2, $p < 0.05$

Xirouchaki ICM 2008;34:2026

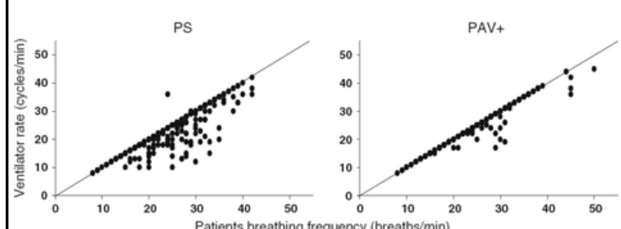
- The use of PAV vs. PSV in critically ill patients for 48 hours
- On controlled ventilation > 36 hours
- Ability to trigger vent > 10/min
- $PaO_2 > 60$ with $F_IO_2 < 0.65$ and total PEEP < 15 cmH_2O
- pH > 7.30
- No severe hemodynamic instability
- No severe bronchospasm
- A stable neurological status



Xirouchaki ICM 2008; 34:2026

Xirouchaki ICM 2008; 34:2026

- Failure rate 11% vs. 22%, p = 0.04
- Proportion of patients exhibiting pt-vent dys-synchrony 5.6% vs. 29%, $p < 0.001$
- The proportion of patients meeting criteria for unassisted breathing did not differ



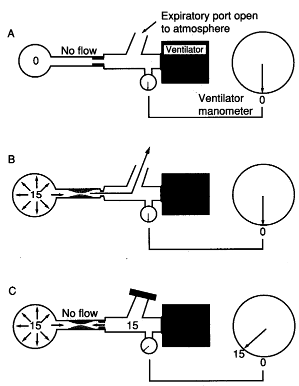
Xirouchaki ICM 2008; 34:2026

Bosma CCM 2007;35:1048

- PSV vs. PAV during sleep, cross over study one night each mode, randomly applied
- Both set to decrease inspiratory WOB by 50%
- MV and V_T lower and CO_2 greater PAV
- Arousals/hr 16 (2-74) vs. 9 (1-41) $p < 0.02$
- Overall sleep quality better PAV $p < 0.05$
  - Awakenings/hr 5.5 (1-24) vs. 3.5 (0-24)
  - Rapid eye movement 4% 90-23) vs. 9% (90-31)
  - Slow wave sleep 1% (0-10) vs. 3% (0-16)
- Asynchronies/hr 53$\pm$59 vs. 24$\pm$15 $p < 0.02$

Proportional Assist Ventilation

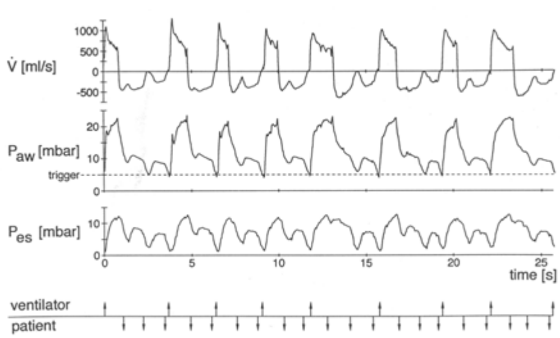
- Requires patients have an intact ventilatory drive!
- Requires ongoing assessment of lung mechanics!
- Unable to deal with auto-PEEP!!



Pepe ARRD 1982;126:166

Auto - PEEP

- The same effect on lung volume and intrathoracic pressure as applied PEEP
- Except auto – PEEP only develops in lung units with long time constants, that is parts of the lung where compliance or airway resistance are increased
- Auto – PEEP affects cardiovascular status the same way as applied PEEP

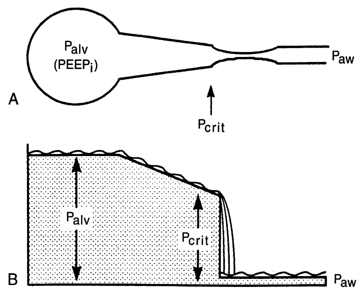


Fabry Chest 1995;107:1387

Auto-PEEP – Work of Breathing

Alveolar Pressure	+10 cmH_2O
Airway Pressure	0 cmH_2O
Trigger Pressure	-2 cmH_2O
Patient Pressure change needed to trigger	-12 cmH_2O

PEEP Aplication



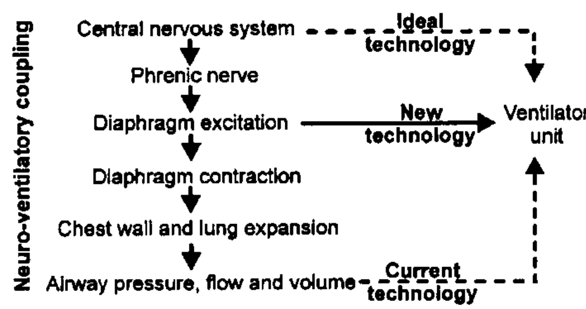
Gottfried SB, Ventilatory Failure (Spring-Verlag),1991

PEEP – Assisted Ventilation COPD

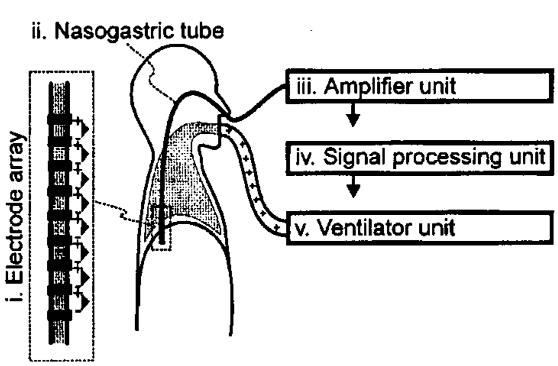
- If auto-PEEP measured, set PEEP at 80% of measured level
- If auto-PEEP unmeasured, set PEEP at 5 cmH_20
- If untriggered breathes still present, increase PEEP in 1 to 2 cmH_2O steps until patient rate and ventilator response rate are equal

NAVA

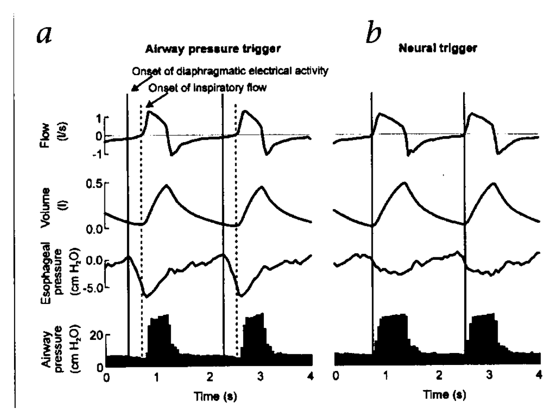
Neurally Adjusted Ventilatory Assist



Sinderby Nature Med 1999;5:1433



Sinderby Nature Med 1999;5:1433



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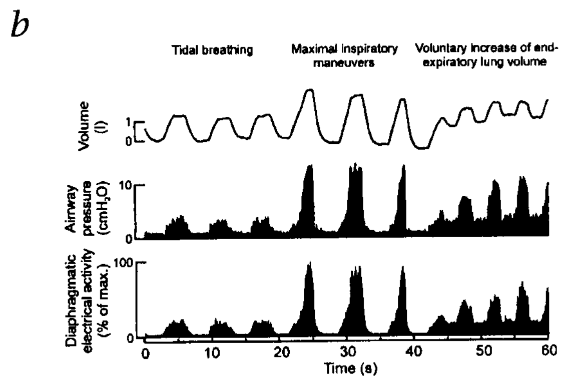

Sinderby Nature Med 1999;5:1433

NAVA

- Beck ICM 2008;34:316
  - Able to deliver NPPV to lung injured rabbits
- Sinderby Chest 2007;131:711
  - Able to cycle on and off during maximal inspiratory effort in humans
- Beck Pediatr Res2007;61:289
  - Unloads diaphragm better than PSV in healthy rabbits
- Allo CCM 2006;34:2997
  - Unload effort in lung injured rabbits without large V_T
- Colombo ICM 2008;34:2010
  - Less over-assistance, better pt-vent synchrony

Thank You