New Modes of Ventilation: Should be Using Them?

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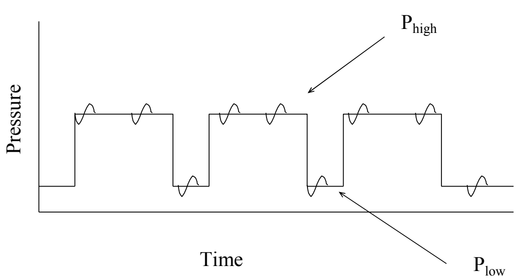
FOCUS 2010

Potential Conflicts of Interest

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

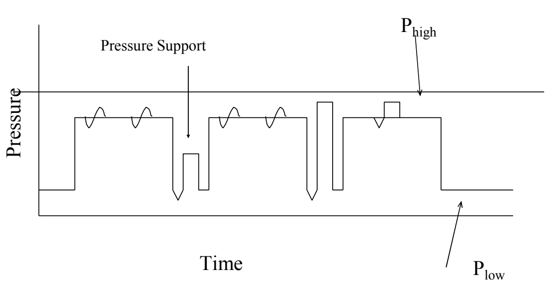
APRV



APRV and Patient – Ventilator Dyssynchrony

- Two periods during APRV that are particular vulnerable to patient – ventilator dyssynchrony
  - When airway pressure is released during spontaneous inspiration
  - When airway pressure is increased during spontaneous exhalation
- This is similar to the dyssynchrony that occurs during IMV as opposed to SIMV
- Ideally, Hi and Low CPAP times should be coordinated to avoid dyssynchrony!

Bi-Level

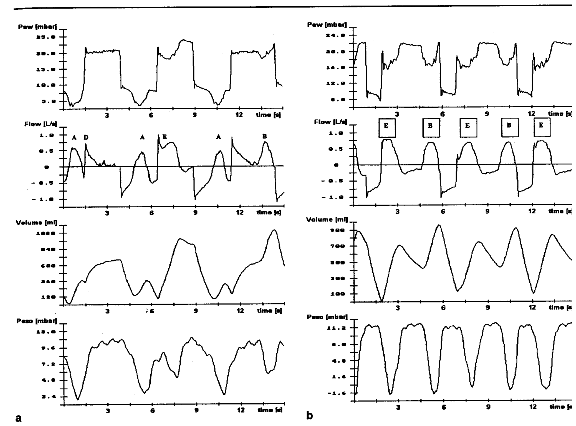


Inverse Ratio: APRV and Bi-level

- High CPAP 2 to 4 sec, 20 to 30 cmH_2O
- Low CPAP < 1.0 sec, 0 to 10 cm H_2O
- Purposefully create autoPEEP
- Only decrease lung volume to about 2/3 end inspiratory volume
- Spontaneous breathing only at High CPAP
- No application of PSV

Non- Inverse Ratio: APRV and Bi-level

- High CPAP 1 to 2 sec, 20 to 30 cmH_2O
- Low CPAP 1to 3 sec, 0 to 10 cm H_2O
- autoPEEP not created
- Exhalation complete High to Low CPAP
- Spontaneous breathing at both High and low CPAP
- PSV can be applied at both high and Low CPAP



Neuman ICM 2002;28:1742

Putensen AJRCCM 2001; 164:43

- All patients both groups P-V curve (daily)
- PEEP or low CPAP P_{flex} + 2
- Maximum pressure or high CPAP < UIP
- Vt 7 mL/kg
- Rate $PaCO_2$ 45 to 55
- Inspiratory and expiratory time set to allow flow to return to zero (auto-PEEP not measured)

TABLE 2. OUTCOME DATA*

	APRV Group	PCV Group	p Value
Number of patients, n (%)	15 (100)	15 (100)	–
Survivors, n (%)	12 (80)	11 (74)	ns
ARDS, n (%)	3 (20)	11 (74)	0.015
ALI non ARDS, n (%)	8 (53)	4 (27)	0.019
Extrapulmonary organ failure, n (%)†			
1	8 (53)	10 (67)	ns
2	6 (38)	7 (47)	ns
≥ 3	1 (9)	0 (0)	ns
Sepsis, n (%)	9 (75)	10 (30)	ns
Length of ventilatory support, d	15 ± 2	21 ± 2	0.032
Length of intubation, d	18 ± 2	25 ± 2	0.011
Length of ICU stay, d	23 ± 2	30 ± 2	0.032

Putensen AJRCCM 2001;164:43

Putensen AJRCCM 2001; 164:43

- APRV - spontaneous breathing
  - Ramsey score 3
- PCV - controlled vent 72 hours
  - Ramsey score 5 to 6
  - Neuromuscular paralysis
  - After 72 to APRV

Smart Care - Closed Loop PSV

- PSV – closed loop control of *f*, tidal volume and end tidal CO_2
- Output: Pressure, adjustments in 2-4 cm H_2O steps every 2-4 minutes
- Lowest PSV which
  - 15> *f* < 30 b/min, 34 b/min COPD
  - V_T >250 mL to 300 mL based on size
  - $P_{ET}CO_2$ <55, < 65 COPD
- If PSV is stable at low level– suggests SBT

Lellouche, Brochard AJRCCM2006;174:894

- Time to extubation days:
  - 2 (1.76-6.25) vs. 4 (2-8.25) $p < 0.02$
- Duration of MV days:
  - 6.5 (3-12.25) vs. 9 (5.75-16) $p < 0.03$
- Total MV days:
  - 7.5 (4-16) vs. 12 (7-26), $p < 0.003$
- ICU LOS days:
  - 12 (6-22) vs. 15.5 (9-33), $p < 0.02$
- Post extubation need for NPPV:
  - 14 (19%) vs. 26 (37%), $p < 0.02$

Lellouche, Brochard AJRCCM2006;July13th

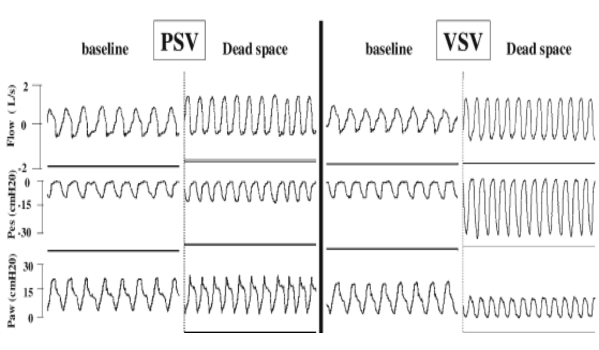
- No difference in reintubation rate, self extubation, trach, MV for > 14d and 21d
- No difference in the use of sedatives, opioids, neuromuscular blockers, and corticosteroids
- However, compliance rate for SBT in the standard of care group was 51%!
- The SBT trial criteria differed among the 5 centers!

PRVC and VS

- Pressure regulated volume control and Volume support
- Both target a preset V_T and adjust the level of pressure ventilation (1 to 3 cmH_2O) as needed to ensure the delivery of the V_T
- PRVC - set rate, inspiratory time, V_T and pressure limit
- VS - set V_T and pressure limit
- Test breath calculates pressure needed to deliver V_T

PRVC/VS

- Two randomized weaning trials
- Piotrowski ICM 1997;23:975
  - PRVC vs. IMV neonates
  - PRVC weaned faster and greater IVH with IMV
- Randolph JAMA 2002;288:2561
  - VS vs. PS with protocol vs. PS without protocol pediatric patients
  - No diff in time to wean or wean rate

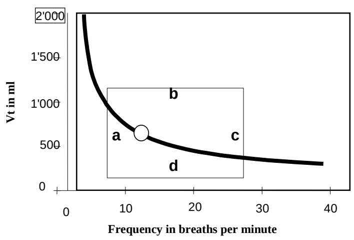


Jabar ICM 2005;31:1181

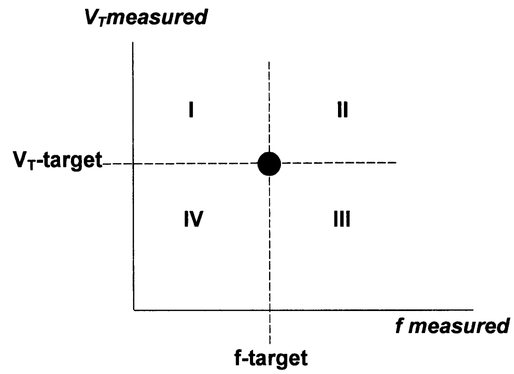
Adaptive Support Ventilation

- Designed to force the patient to maintain a minimum minute ventilation using an “optimal breathing pattern” based on work of breathing as described by Otis
- A frequency and tidal volume producing the minimal work of breathing is targeted
- Frequency and tidal volume target change over time as lung mechanics change: dynamic compliance and the respiratory time constant are measured
- Maximum rate determined by the respiratory time constant
- Must input % minute volume (25 to 350% of ideal), ideal body weight and maximum pressure limit!

Calculate Optimal Breath Pattern: Least Work of Breathing



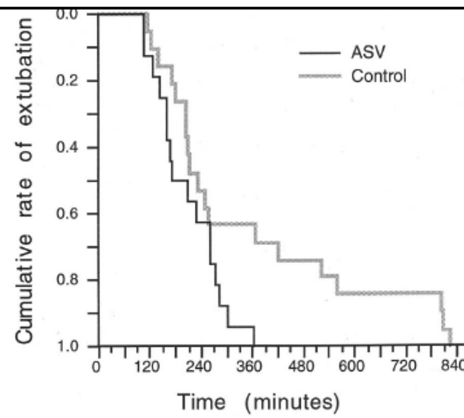
Avoid:
a: apnea
b: volu/barotrauma
c: AutoPEEP
d: excessive V'_D/tachypnea



Campbell RC Cl NA 2001;9:425

Adaptive Support Ventilation

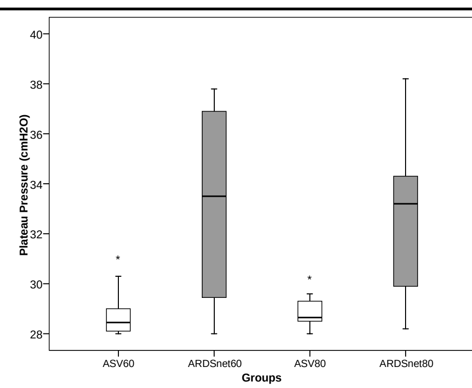
- **Arnal ICM 2008;34:75** – 243 patients with various causes of respiratory failure; ASV in control ventilation selected different combination of RR/V_T based on the patients Respiratory mechanics. In spon breathing pts RR/V_T did not differ.
- **Cassina J Cardioth Vas Anes 2003;17;571** – 155 Cardiac surgical pts ASV safe, easy to use, rapid extubation
- **Peter Crit Care Trauma 2003;97:1743** – Elective Cardiac Surgery (n=34) ASV vs. IMV/PS weaning. No difference except less vent changes ASV



Sultzer Anes 2001;95;1339

Sulemanji Anes 2009 Accepted

- A fix 6 ml/kg VT vs. ASV in lung model simulated ARDS
- Ability to maintain Pplat < 28 cmH_2O
- 60 and 80 kg PBW
- Compliance range 45 to 15 ml/cmH_2O
- Resistance 5 and 10 cmH_2O/L/min
- PEEP 8, 12, 16 cmH_2O
- Minute Volume 120%, 150% and 200% of predicted
- 108 unique conditions evaluated



Plateau Pressures ≥ 28 cmH_2O 24 times in ASV vs. 40 times fixed V_T 6 ml/kg

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 lung mechanics and adjusts ventilator output to reduce work
- Introduced by Younes in 1992

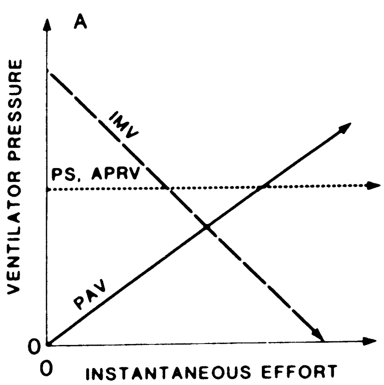
(Younes M, ARRD 1992;145:121)

Equation of Motion for the respiratory system

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

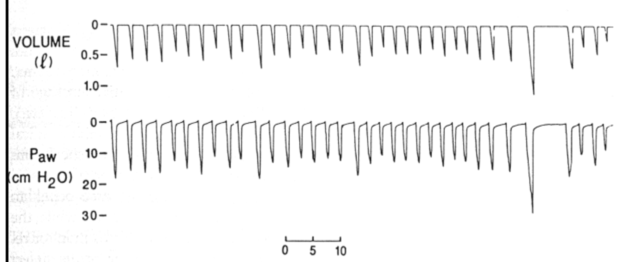
$$Paw + Pmus = V' \times R + \Delta V \times E$$

Patient response: Mechanical, Chemical, Reflex, Behavioral

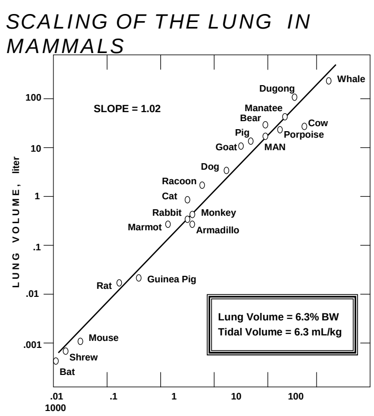


Younes ARRD 1992;145:114

PAV



Younes M. AARD 1992;145:121



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

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

PAV versus PSV

- PAV preserved the ability of patients to modulate V_T in response to hypercapnia and changes in lung mechanics
- 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

Kondili ICM 2006;32:692

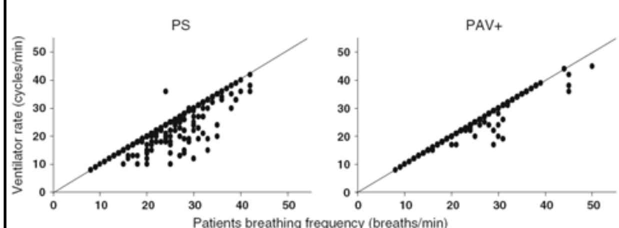
- PAV vs. PSV in 10 Pts in ARF with load increased by sand bags on their chest and abdomen, $\geq$ 30% increase in elastic resistance!
- PAV improved pt – vent synchrony: better matching of initial flow and cycling!
- With PAV V_T increased more than with PSV and RR increased less but MV was the same
- During PAV the PTP of the diaphragm was less per breath, per minute, and per liter of ventilation

Kondili Anes 2006;105:703

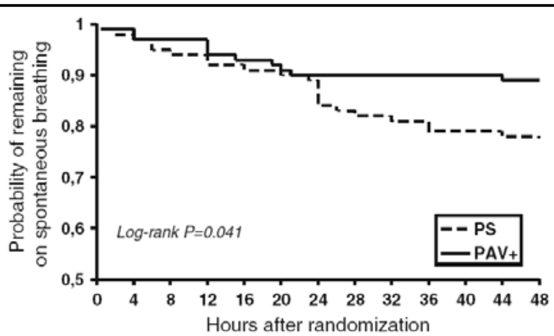
- PAV vs. PSV in 12 patients with ALI/ARDS due to sepsis, P/F 190$\pm$49 mmHg
- 30 min in random order mean airway pressure constant
- PAV - RR higher 24.5+6.9 vs. 21.4+6.9, $p < 0.05$
- PAV - V_T lower 7.7+1.9 vs. 8.0+1.6 ml/Kg but not significantly
- PAV - CI higher 4.4+1.6 vs. 4.1+1.3 L/min/m^2, $p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

Xirouchaki ICM 2008;On Line

- The use of PAV vs. PSV in critically ill patients for 48 hours
- On controlled ventilation > 36 hours
- Ability to trigger vent > 10/min
- PaO2 > 60 with FIO2 < 0.65 and total PEEP < 15 cmH2O
- pH > 7.30
- No severe hemodynamic instability
- No severe bronchospasm
- A stable neurological status



Xirouchaki ICM 2008;On Line



Patients at risk

PS	100	92	84	79	78
PAV+	108	101	97	97	96

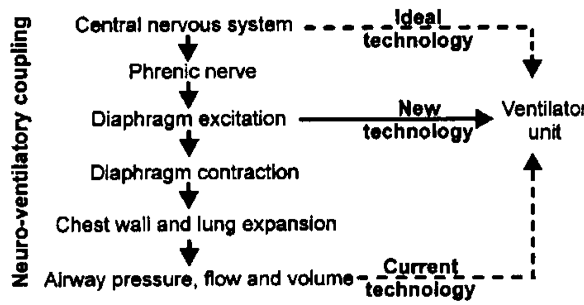
Xirouchaki ICM 2008;On Line

Bosma CCM 2007;35:1048

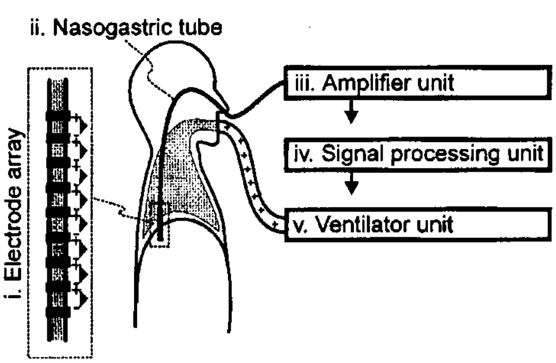
- PSV vs. PAV during sleep cross over study one night each mode randomly applied
- Both set to decrease inspiratory WOB by 50%
- MV and V_T lower and CO_2 greater PAV
- Arousals/hr 16 (2-74) vs. 9 (1-41) $p < 0.02$
- Overall sleep quality better PAV $p < 0.05$
  - Awakenings/hr 5.5 (1-24) vs. 3.5 (0-24)
  - 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 $p < 0.02$

NAVA

Neurally Adjusted Ventilatory Assist



Sinderby Nature Med 1999;5:1433



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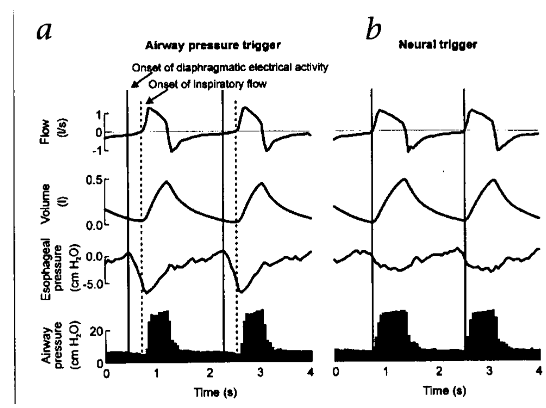

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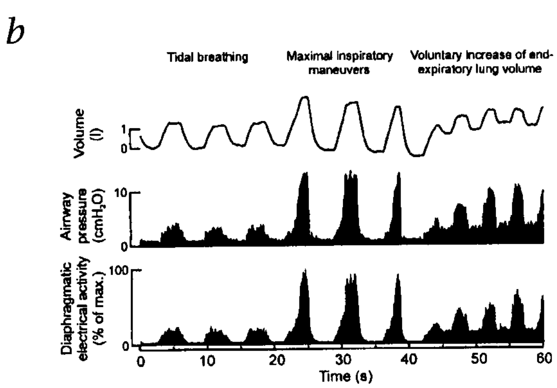

Sinderby Nature Med 1999;5:1433

Beck Pediatric Research 2009;65:663

- 7 Infants, 936 gms,
- Patient ventilator synchrony during noninvasive and invasive ventilation with NAVA vs. PA/C for 30 min.
- Pressure delivered during PA/C was not correlated with EAdi. Neural inspiratory time was longer and RR lower with NAVA and cycle off delay was lower with NAVA than PA/C ($p < 0.05$)
- No serious adverse events

Bengstson Pedi CCM 7/7/2009 (Epub ahead of print)

- 21 children 2 days to 15 years of age most post cardiac surgery
- NAVA vs. PSV each for 1 to 6 hour periods
- With NAVA PIP decreased, RR increased. and tidal volume decreased $p < 0.05$
- With NAVA neural trigger 69% and neural cycle 88%
- No serious adverse events

Breatnach Pedi CCM 7/7/2009 (Epub ahead of print)

- 16 children, 9.7 months
- PAV vs. NAVA 30 min to 4 hours
- With NAVA 65% of breaths triggered neurally $p < 0.001$
- With NAVA 85% of breaths cycled off neurally $p < 0.0001$
- PIP 30% lower with NAVA than PSV $p = 0.003$
- No serious adverse events

Colombo ICM 2008;34:2010

- 14 intubated MV adults
- PSV V_T 6-8 ml/kg vs. NAVA matched to PSV
- Both modes increased and decreased 50%
- No ABG differences.
- Little difference among all measurements at the two lower assist levels
- At highest level V_T was higher (9.1 vs. 7.2 ml/kg), RR lower (12 vs. 18/min) and Peak EAdi higher 8.6 vs. 12.3) (all $p < 0.05$) in PSV
- No serious adverse events

Brander Chest 2009;135:695

- 15 adults with $PaO_2/F_IO_2 < 300$ mmHg
- Systemically adjust NAVA levels evaluating the effect on various respiratory variables.
- Compared to conventional ventilation NAVA resulted in:
  - Lower tidal volume
  - More rapid RR
  - Lower PIP
- Systemically increasing NAVA level
  - Reduces respiratory Drive
  - Unloads respiratory muscles

PAV vs. NAVA

- PAV
  - Uses airway pressure and flow measurements
  - No specific equipment needed
  - Available invasively/noninvasively (different ventilators)
  - Use with patients greater than 20 kg
  - Affected by leaks (current invasive) and autoPEEP
- NAVA
  - Uses measurement of diaphragm EMG (EAdi) activity
  - Requires use of a special catheter
  - Available invasively/noninvasively
  - Useful in neonates, children and adults
  - Unaffected by leaks and autoPEEP

Thank You