Restful Ventilation

Do Ventilator Settings Influence Sleep Quality in the ICU?

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Case Study

- 56 year old male
- 40 pack year smoker, obese, hypertension
- Aortic valve replacement complicated by ARDS and acute kidney injury – now resolved
- Prolonged wean from mechanical ventilation
- Tracheostomy
- Looks comfortable on PSV 12 cmH_2O, PEEP 5
- Tolerates 1-2 hours of trach-mask trials per day
- Walks 15 m on portable vent with physiotherapist

Audience Poll

1. Is it beneficial to rest this patient at night?
   - Yes, patient will wean better during day if rested overnight
   - No, more beneficial to continue weaning efforts overnight

Audience Poll

1. Is it beneficial to rest this patient at night?
   - Yes, patient will wean better during day if rested overnight
   - No, more beneficial to continue weaning efforts overnight
2. How do you rest the patient at night?
   - Increase Pressure Support level?
   - Assist – Control mode?
   - Controlled mechanical ventilation?

Audience Poll

3. How do you confirm that the patient is “resting” and comfortable?
   - Target respiratory rate <20? < 30? <40?
   - Target f/Vt?
   - Blood gases are good and patient is not complaining…

Audience Poll

3. How do you confirm that the patient is “resting” and comfortable?
   - Target respiratory rate <25? < 35? <45?
   - Target f/Vt?
   - Blood gases are good and patient is not complaining…
4. Will good quality sleep help this patient wean from the ventilator?

Rhetorical Question

- Isn't question #4 the same as question #1?
- Does resting the patient's respiratory muscles = better sleep??

Outline

- Why sleep might be important for weaning
- What happens to breathing pattern during sleep
- Patient-ventilator interaction and sleep
  - Central Apnea
  - Ineffective Efforts
- Does resting the patient's respiratory muscles = better sleep??
- ***In assisting the patient's breathing, how you set the ventilator is important…***
  How you do what you do matters!

Is Sleep Important in the ICU?

- No sufficient outcome studies that objectively quantify sleep quantity and quality in ICU
- May contribute to delirium, increased 6 month mort
  days and longer ho

•In a study of 62 critically ill patients, delirium in

•33% of patients with severe sleep 'sruption

0% of patients with oderate sleep sruption

% of patients with lequate sleep.

•275 consecutive patients requiring MV (224 survived ICU and included in study)

•82% developed delirium

•6 month mortality 35% vs 15%

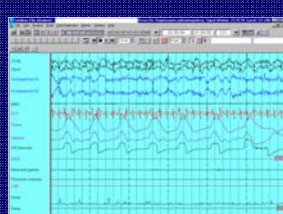
•Ventilator-free days median 19 vs 24

•Ave 10 days longer in hospital

Extrapolating from other populations…

- Sleep loss impairs respiratory muscle endurance in healthy males
  - *Muscle strength (MIP, MEP) FEV1, FVC not affected*
  - Chen HI, Tang YR. Am Rev Resp Dis 1989; 140:907-9
- Sleep deprivation depresses immune function in healthy adults
  - Irwin M et al. FASEB J 1996; 10:643-653
  - Multiple basic science studies
- Sleep disruption (arousals/hr on polysomnography) strongly associated with mortality risk in patients with end-stage renal disease and sleep disorders
  - Benz RL et al. Am J Kidney Dis 2000; 35:1052-60

Polysomnography



Polysomnography is the gold standard for sleep measurement

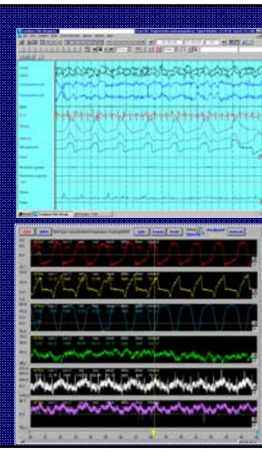
A Brief Primer on Sleep Quantification

- Quantity:
  - Sleep Efficiency = % of time in bed spent asleep
  - Sleep Maintenance Efficiency = % of time asleep from sleep onset to final morning awakening
- Quality:
  - Sleep architecture: Of total sleep duration, % time spent in each sleep stage
  - Stage 1 and 2 are light stages, Stage 3 and 4 (Slow Wave Sleep) are deep stages, and REM (dream stage)
- Fragmentation
  - # Arousals and Awakenings / hr sleep time

Sleep in the ICU is highly abnormal

- Up to 2/3 of ICU patients do not have EEG patterns consistent with typical "sleep", but rather coma, encephalopathy or suppression due to sedation
- In patients who have periods of wakefulness and sleep, pattern is very abnormal:
  - Sleep during day and night (loss of circadian rhythm)
  - Higher amount of Stage 2 and little to no slow wave sleep (SWS) and REM
  - Highly fragmented – 2-3x normal and equivalent to patients with severe untreated obstructive sleep apnea

Equipment

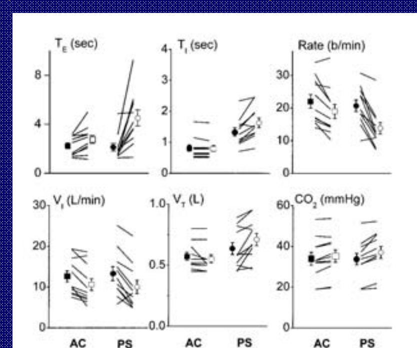


Breathing during sleep

- Downregulation of respiratory muscles
- Decreased VE due to decreased Vt
- CO_2 rises: 2-4 mmHg higher during sleep
- REM sleep: paralysis of major muscle groups with exception of diaphragm and upper airway muscles
- RR variable

From Wakefulness to Sleep on PSV and ACV

(Am J Respir Crit Care Med 2002; 166:1423-1429)



Ventilator and RT Response: PSV and ACV

- Preset target levels for pressure and cycling off, so ability for patient to modulate VE may be limited
- Increased inspiratory time on PSV during sleep→ increased tidal volumes
- On ACV, no change in Vt: minute ventilation will depend on patient's RR and backup rate
- If patient wakes, RR will climb → increase level of support
- CO_2 climbs – 7 mmHg higher on PSV → increase level of support

Patient-Ventilator Interaction

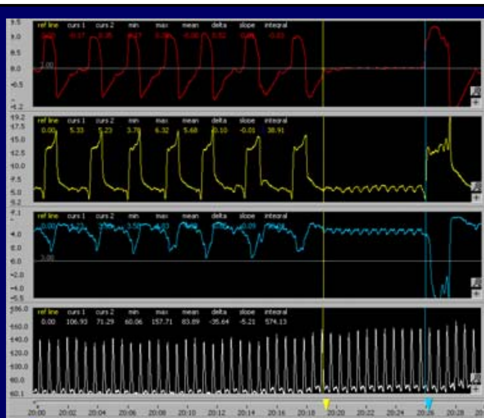
- 2 considerations for optimal interaction between patient and ventilator:
- A) Agreement between magnitude of patient inspiratory effort and amount of ventilator support
- B) Synchrony between timing of the patient effort and ventilator-delivered breath

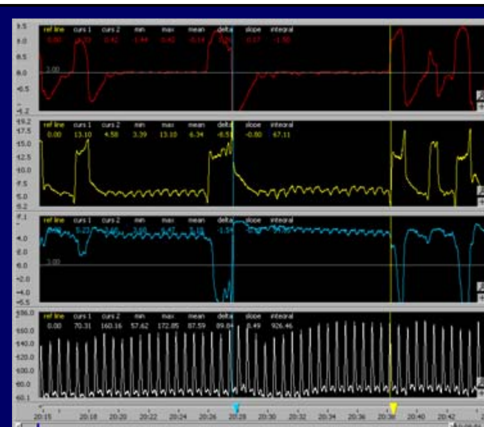
Central Apnea ← Over-ventilation

- Patient's respiratory drive decreases in response to decreased minute ventilation requirements, but minute ventilation provided by ventilator does not decrease proportionally
- CO_2 falls below the apneic threshold
- Patient stops making respiratory efforts
- CO_2 rises above apneic threshold
- Respiratory efforts resume

Central Apnea

- Patients with congestive heart failure more prone to this, but even health subjects with normal lungs can develop apnea during PSV when their PCO_2 decreases by a few mmHg (below the apneic threshold)
  - Meza, Younes et al J Appl Physiol 1998;85:1929-40
- May common during sleep
- "physiologic apnea" –pH may be in normal range to alkalotic
- *not to be confused with drug-induced apnea – if untreated, pH < 7.35





Do central apneas disrupt sleep?

- Parthasarathy and Tobin
- (Am J Respir Crit Care Med 2002; 166:1423-1429)
- 11 ICU patients on MV: PB 7200, ETT or trach
- Measured airflow, airway pressure, ribcage and abdominal motion, pulse oximetry, ECG
- Polysomnography (to record sleep)
- Between 10 pm and 6 am, pts spent 2 hours each on ACV, PSV and PSV with 100 ml of added dead space

Parthasarathy and Tobin Study

(Am J Respir Crit Care Med 2002; 166:1423-1429)

- **AC:** backup rate initially set at 4 breaths/min and Vt 8 ml/kg. Patient's respiratory rate observed over 5-10 minutes of quiet wakefulness. Then, AC rate set to 4 breaths below that patient's RR for 2 hours
- **PSV:** adjusted to achieve a Vt of 8 ml/kg

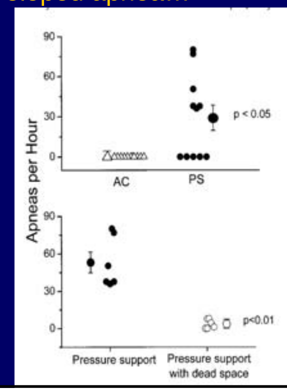
Results

*significantly different from PSV p <0.05

	AC	PSV	PSV + Deadspace
Duration of sleep (min)	**90 ± 6**	**75 ± 6**	**82 ± 7**
Sleep efficiency (%)	**75 ± 5***	**63 ± 5**	**81 ± 7***
Arousals + Awakenings (# / hr sleep)	**54 ± 7***	**79 ± 7**	
Central Apneas (# of patients)	**0 /11***	**6 /11**	
Apnea-related arousals + awakenings (# / hr)	**0***	**23 ± 7**	

For 6 patients who developed apnea…

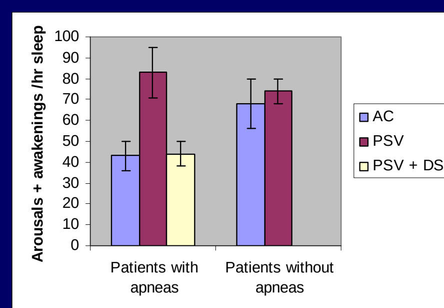
- Addition of deadspace decreased the frequency from 53 ± 8 to 4 ± 2 apneas/hr
- History of CHF more common among patients with apneas than those without apneas
  (83 vs 20%)



How can you reduce occurrence of apneas?

- Addition of deadspace (compensate for the over-ventilation)
- A/C back up rate (may over-ventilate but over-ride the central apnea)
- Look for and reduce autotriggering if that is the cause of over-ventilation
- Lower Vt → decrease PSV (+/- increase cycling off criteria to >25% peak flow)

Parthasarathy and Tobin study



Patient-Ventilator Interaction

- 2 considerations for optimal interaction between patient and ventilator:
- A) Agreement between magnitude of patient inspiratory effort and amount of ventilator support
- B) Synchrony between timing of the patient effort and ventilator-delivered breath

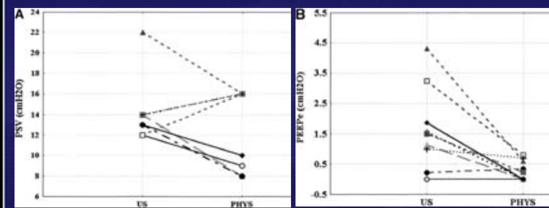
- What if we set the level of support in accordance with the patients' effort?

Fanfulla, Nava and coworkers' study

Am J Respir Crit Care Med 2005; 172:619-624

- 9 patients with neuromuscular disease requiring NIV for hypercapneic respiratory failure
- 2 strategies for setting nPSV:
  - 1. ventilator settings clinically determined in the usual fashion (USUAL)
  - 2. ventilator settings based on the recording of inspiratory muscle effort (measurement of transdiaphragmatic pressure, Pdi): level of support sufficient to decrease the Pdi by 40-80%, PEEPe set at 80% of PEEPidyn (PHYS)
- Each patient had sleep recordings 2 consecutive nights during nPSV using USUAL and PHYS settings (random order)

Results:



Results: Fanfulla and Nava study

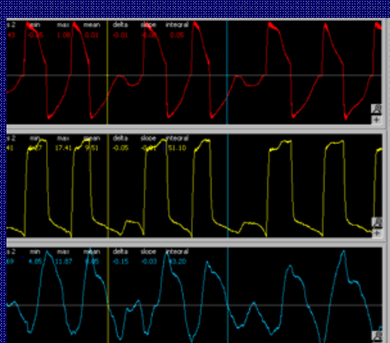
- DAYTIME
- 2 strategies: no difference in daytime patterns of breathing, blood gases, or respiratory mechanics
- BUT, PEEPidyn was significantly lower during PHYS setting than USUAL setting

Results: Fanfulla and Nava study

*significant difference, $p<0.05$

	USUAL	PHYS
Sleep efficiency (% of TST)	66 ± 22	81 ± 10*
REM sleep (% of TST)	9 ± 7	17 ± 5*
Arousals (# / hr sleep)	30 ± 17	16 ± 13*
Central apneas (# of patients)	3 / 9	1 / 9
Ineffective efforts (# / hr during NREM sleep)	62 ± 75	15 ± 20*

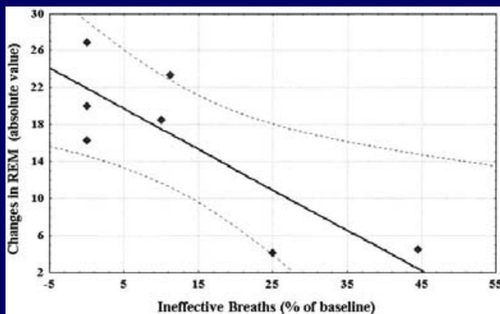
Ineffective Triggering



Ineffective Triggering

- Peak patient effort < intrinsic PEEP + set trigger sensitivity
- Amount of Auto-PEEP present at onset of inspiration increases if:
  - Vt is large (higher PSV levels)*
  - Te is short (higher spontanous RR)
  - Expiratory resistance is high (flow limitation → rate of lung emptying is reduced)

Reduction in Ineffective Efforts correlates with Increase in REM sleep



Asynchrony

- If goal is to rest the respiratory muscles, then it is important that a patient not make respiratory efforts out of synchrony with the cycling of the ventilator
  - → Ineffective efforts = wasted energy

How can you reduce the occurrence of ineffective efforts?

- Goal: less dynamic hyperinflation
- Reducing PSV level +/- decrease insufflation time (increase % of peak flow threshold for cycling off)
- A study of 12 intubated patients on PSV demonstrated that reducing PSV from 20 to 13 cmH_2O reduced Vt from 10 ml/kg to 6 ml/kg, and abolished ineffective efforts with no change in patient's effort, intrinsic RR or CO_2;
  - Applying PEEPe had no effect
  - Thille, Brochard et al. Intensive Care Med 2008;34:1477-86

Study Rationale: Bosma, Ranieri et al.

Crit Care Med 2007;35:1048-54

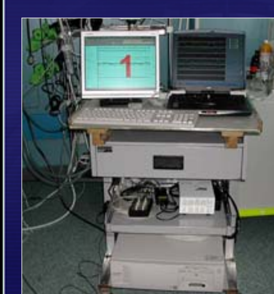
- Patient-ventilator asynchrony causes sleep disruption?
- Proportional assist ventilation (PAV) provides support in proportion to patient effort and therefore should improve patient-ventilator synchronization
- Sleep should be better on PAV vs. PSV

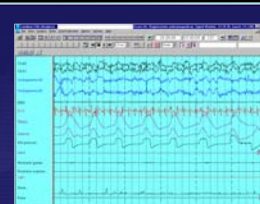
Bosma, Ranieri and coworkers' study

Crit Care Med 2007;35:1048-54

- 13 stable ICU patients weaning from MV
- 2 modes: PSV and PAV (Evita 4, Dräger)
- Level of support set to offload work of breathing by 50% relative to spontaneous breathing
  - Esophageal balloon – Pes
  - Set level of support to achieve Pes 50% of spontaneous
- 2 consecutive nights on PAV and PSV (random order) recording sleep and breathing pattern

Equipment

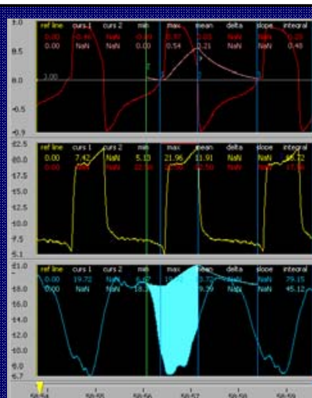




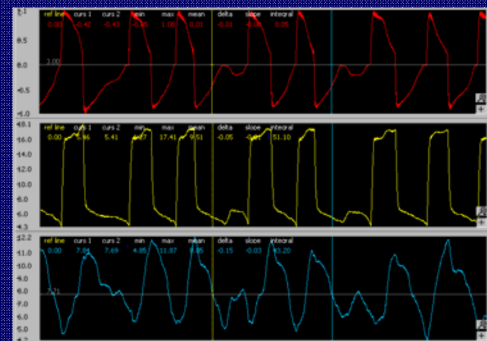
PSV

Measurement of Pressure Time Product (PTP)

Unit = cmH_2O*s per breath, per minute or per LE



Patient-Ventilator Asynchrony



Patient-Ventilator Interaction

- Magnitude of inspiratory effort should match level of support from ventilator
- Pressure, PTP of patient relative to ventilator
- PEEPi
- Apneas

- Timing of inspiratory effort should match timing of ventilator response
  - Asynchronies:

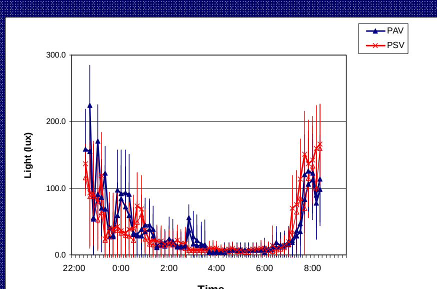
	Ventilator Breath	Patient Breath
AT	1	0
IE	0	1
DT	2	1
DC	1	2

Results: Equivalent Support

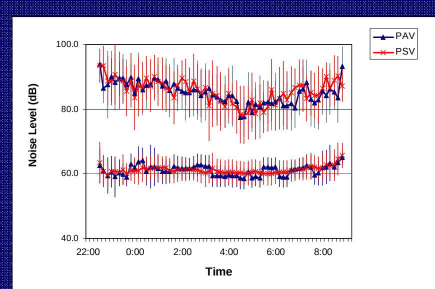
Baseline Unloading of the Respiratory Muscles

	SB	PAV		PSV	
	Mean ± SD	Mean ± SD	(% of SB)	Mean ± SD	(% of SB)
Δ Pes (cmH_2O)	18.5 ± 9.1	8.9 ± 5.1	**(47%)**	8.6 ± 4.4	**(47%)**
PTP/b (cmH_2O·s)	14.1 ± 5.1	8.2 ± 5.0	**(55%)**	7.4 ± 3.7	**(51%)**
PTP/min (cmH_2O·s/min)	398 ± 203	190 ± 114	**(47%)**	182 ± 87	**(48%)**
PTP/L (cmH_2O·s/L)	27.4 ± 12.2	14.2 ± 7.7	**(54%)**	12.3 ± 5.3	**(48%)**

Environmental Light



Environmental Noise



Respiratory Variables During PAV and PSV

*significant difference, p<0.05

	PAV	PSV
PTP/min (cmH_2O*s/min)	197 ± 78	174 ± 56
Vt (mL)	590 ± 130	630 ± 130*
RR (breaths/min)	24.5 ± 6	24.2 ± 5
VE (L/min)	13.5 ± 2.3	14.4 ± 2.7*
Pao (cmH_2O)	11.7 ± 3.5	13.3 ± 3.2*
$P_{et}CO_2$ (mmHg)	39 ± 7	37 ± 5*

Asynchrony

	PAV	PSV
Apneas (n patients)	0	2
Total Asynchronies (n/h)	23.7 ± 15.4	52.9 ± 59.2*

*P<0.05

Sleep Quantity

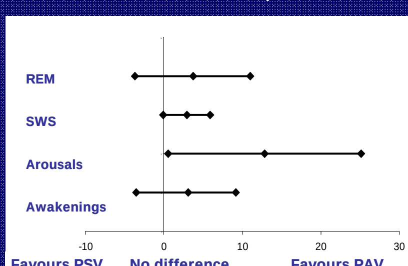
	PAV	PSV	Pvalue
%SE	60.4 ± 22.9	58.1 ± 25.3	0.78
%SME	69.3 ± 22.5	67.7 ± 21.2	0.86

Sleep Quality

	PAV	PSV	Pvalue
Arousals/h	12.8 ± 10.3	25.6 ± 23.2	**0.02**
Awakenings/h	5.2 ± 6.1	8.3 ± 7.5	0.13
Arousals + awakenings/h	18.0 ± 10.4	33.9 ± 28.9	**0.055**
% Stage 3,4	5.0 ± 5.8	2.2 ± 3.2	**0.06**
% REM	10.4 ± 8.1	6.7 ± 8.2	0.35

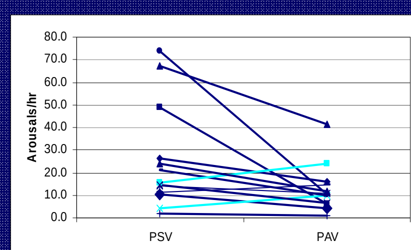
Overall Sleep Quality

Multivariate ANOVA PAV vs. PSV *p<0.05

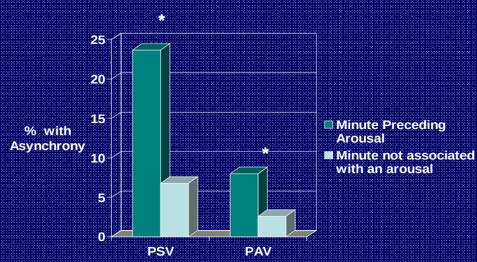


Degree of Improvement

Arousals/hr PSV vs. PAV



Incidence of Asynchrony prior to arousal vs. period of undisrupted sleep



*p < 0.0001 for both PSV and PAV
(pooled data, chi square)

Conclusions from this study

- Patient-ventilator interaction impacts sleep quality
  - Magnitude of inspiratory effort vs. level of support
  - Timing of inspiratory effort vs. timing of ventilator-delivered breath
- PSV settings may be tailored to optimize patient-ventilator interaction, but will continually need readjustment as breathing pattern changes
- PAV automatically tailors ventilator-delivered breath to patient effort and responds to breath-by-breath variability in respiratory pattern

What about other modes?

- SmartCare/PS™ (Evita XL, Dräger) is a computerized closed-loop, knowledge-based system that allows the PS level to be continually adapted to keep the patient in the "comfort zone"
  - Defined as a RR 15-30
  - Vt > 300 mL
  - End-tidal CO_2 < 55 mmHg
- AND automatically tries to reduce the PS to a minimum level

Cabello, Brochard and coworkers' study

Crit Care Med 2008; 36:1749-55

- 15 conscious, stable, nonsedated ICU patients
- 2 pm to 8 am, 6 hours each on ACV, clinically adjusted PSV (cPSV) and automatically adjusted PSV (aPSV) (Evita XL, Dräger), in random order
- Polysomnography x 18 hrs
- ACV: Vt 8 ml/kg, backup rate 10
- cPSV: adjusted to obtain Vt 6-8 ml/kg and RR<35
- aPSV: started at same targets as cPSV

Results: Cabello and Brochard

Crit Care Med 2008; 36:1749-55

- 20 ± 16 changes made in 6 hrs with aPSV compared to 0 changes with cPSV
- Mean PSV did not differ between the modes:
  - 14 ± 8 cmH_2O in aPSV vs 16 ± 6 cmH_2O in cPSV
- No significant differences in Vt, RR, VE between 3 modes

Results: Cabello and Brochard

Crit Care Med 2008; 36:1749-55

	aPSV	cPSV	ACV
Apnea (# patients)	9 / 15	9 / 15	0
Apnea (#/ hr sleep)	5 ± 6	7 ± 11	0
IE (# / hr sleep)	16 ± 45	12 ± 23	7 ± 18

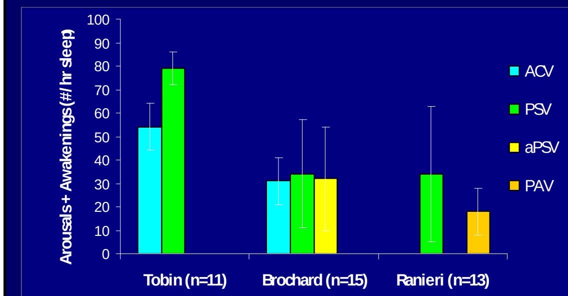
P = NS aPSV vs cPSV
P=0.09 IE on ACV vs. PSV

Results: Cabello and Brochard

Crit Care Med 2008; 36:1749-55

- No differences in sleep quantity, quality or fragmentation between the 3 modes

Comparison of Studies



2 hr each

6 hr each

>8 hr each

Clinical Implications

- ACV may not be better than PSV for sleep
- BOTH modes need to be set accurately to avoid excess support, particularly in patients prone to develop central apneas and ineffective efforts
- Target Vt < 8 ml/kg predicted body weight – closer to 6 ml/kg appears to be better
- RR up to 30-35 appear to be acceptable (20-35)

Clinical Implications

- Any mode/settings that provide inadequate support or excessive support will likely result in poor sleep
- PAV (set properly) may make life easier for the RT and the patient (although it is not for everyone)

Future Research

- Dr R. Kacmarek, Boston, Mass
  - PAV vs PSV for weaning and sleep quality
  - www.clinicaltrials.gov
- Dr. K. Bosma, London, ON
  - PAV vs PSV vs ACV for sleep quality
  - PAV vs PSV for weaning
- Dr. M. Ranieri, Torino, Italy
  - PAV vs ACV vs NAVA for sleep quality

Thank you!

Any Questions?