Is there a role for PAV and NAVA?

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Developing Effective
Hospital Weaning Programs
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critical care canada FORUM

Western

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Disclosure

I hold a CIHR-industry partnered operating grant with Covidien (Medtronic) as the industry partner.

September 24, 2015

Objectives

1. Respiratory system capacity and load
2. How PAV works
3. How NAVA works
4. State of the evidence

Load vs. Capacity

<u>Respiratory System Load</u>

- Need for ↑ VE
  - ↑ CO2 production
  - ↑ dead space
  - ↑ drive
- ↑ work of breathing
  - Altered mechanics:
  - ↓ compliance
  - ↑ resistance

<u>Respiratory System (Neuromuscular) Capacity</u>

Depends upon intact:

- Central drive
- Transmission via phrenic nerve
- Respiratory muscles:
  - generate normal muscle force and effective pressure gradients

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Weaning Failure

TREATMENT: After failed SBT

- Comprehensive evaluation
- Improve physiologic status
- Rehabilitation and recovery
- Choose a mode which:
  - Maintains favourable balance between respiratory system capacity and load
  - Avoids diaphragm atrophy
  - Aids in the weaning process

PREVENTION: Before SBT

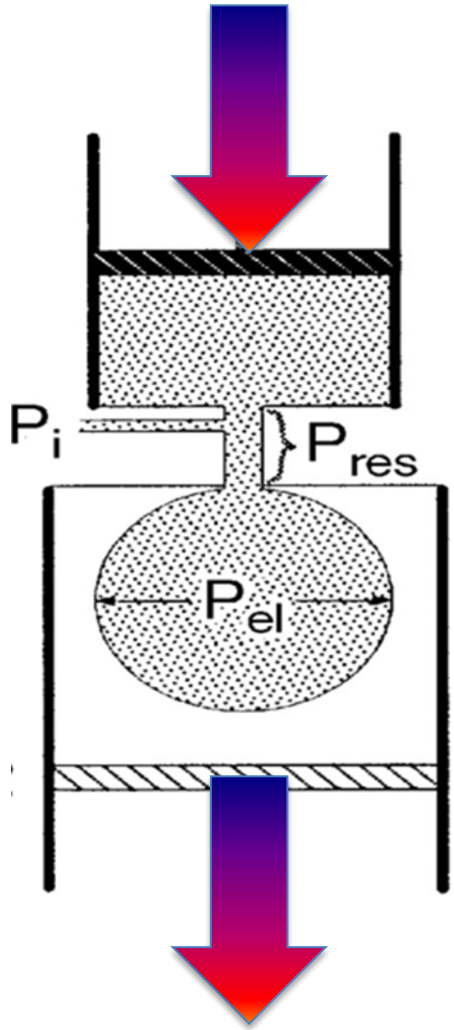
- Optimize patient-ventilator interaction:
  - Avoid asynchrony, over-assistance, diaphragm disuse
- Choose a mode which:
  - Maintains favourable balance between respiratory system capacity and load
  - Avoids diaphragm atrophy
  - Aids in the weaning process

Patient-Ventilator Interaction

$$P_{vent} + P_{mus} = (Flow * Resistance) + (Volume * Elastance)$$

Optimal Patient-Ventilator Interaction:

- Neural Ti = Ventilator Ti
- Level of assistance is proportional to level of need



Suboptimal Patient-Ventilator Interaction

- Asynchrony
  - Wasted energy, inefficient energy use
- Over-assistance
  - Disuse atrophy,
  - Central apneas
  - PEEPi
  - Ineffective efforts

PAV

Pmus = Pres + Pel

= Flow*Rtot + Vt*Est

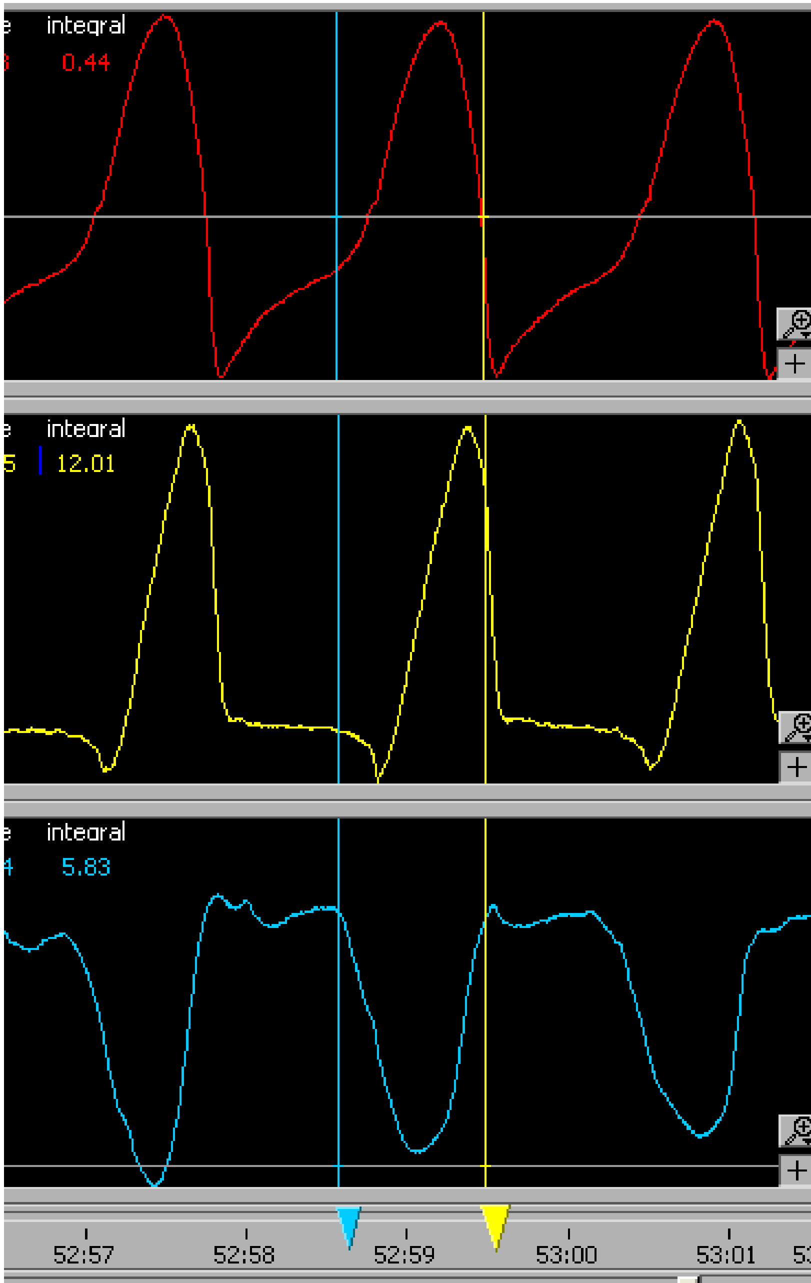
<u>Proportional Assist Ventilation</u>

- Instantaneously measures flow and volume being “pulled in” by the patients
- Ventilator knows the respiratory resistance and elastance
- Therefore calculates instantaneous Pmus
- Provides assistance in proportion to Pmus

Flow

Pao

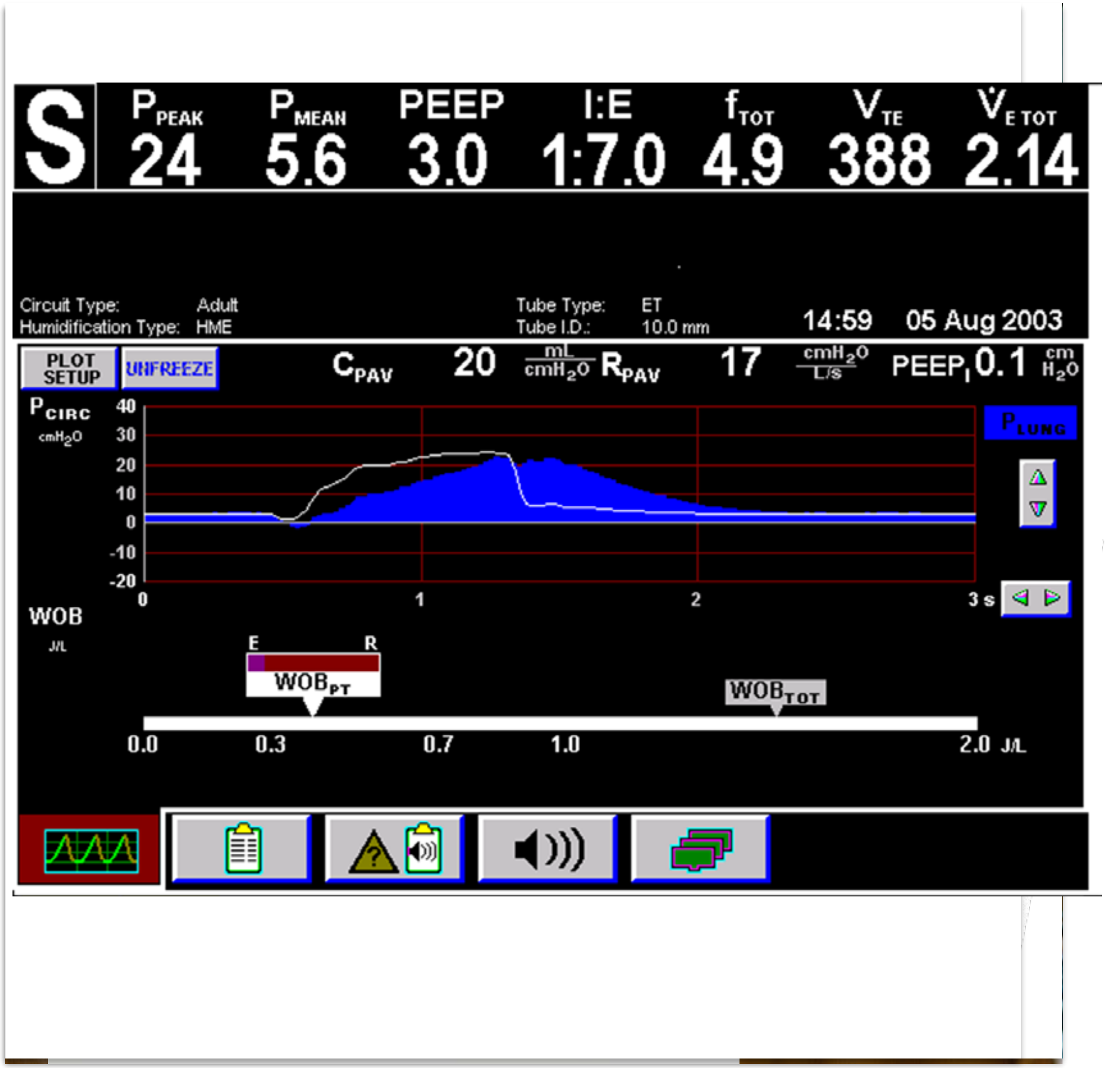
Peso



Invention to Commercialization

- The PAV algorithm was invented by Dr. Magdy Younes, MD, PhD, University of Manitoba, Canada.
- Original Winnipeg Ventilator, 1986
- Patented 1990
- Manual versions of PAV:
  - Evita 4 and XL Ventilators in Proportional Pressure Support Mode (Dräger, Lubeck, Germany)
  - BiPAP Vision Ventilator in PAV Mode (Respironics, Murrayville, Pensylvania, USA)
- Closed-loop PAV (PAV+) is a software package for the Puritan-Bennett 840 ventilator (Covidien, Boulder, Colorado, USA)
- Released in Canada 2005

- Dr. Magdy Younes

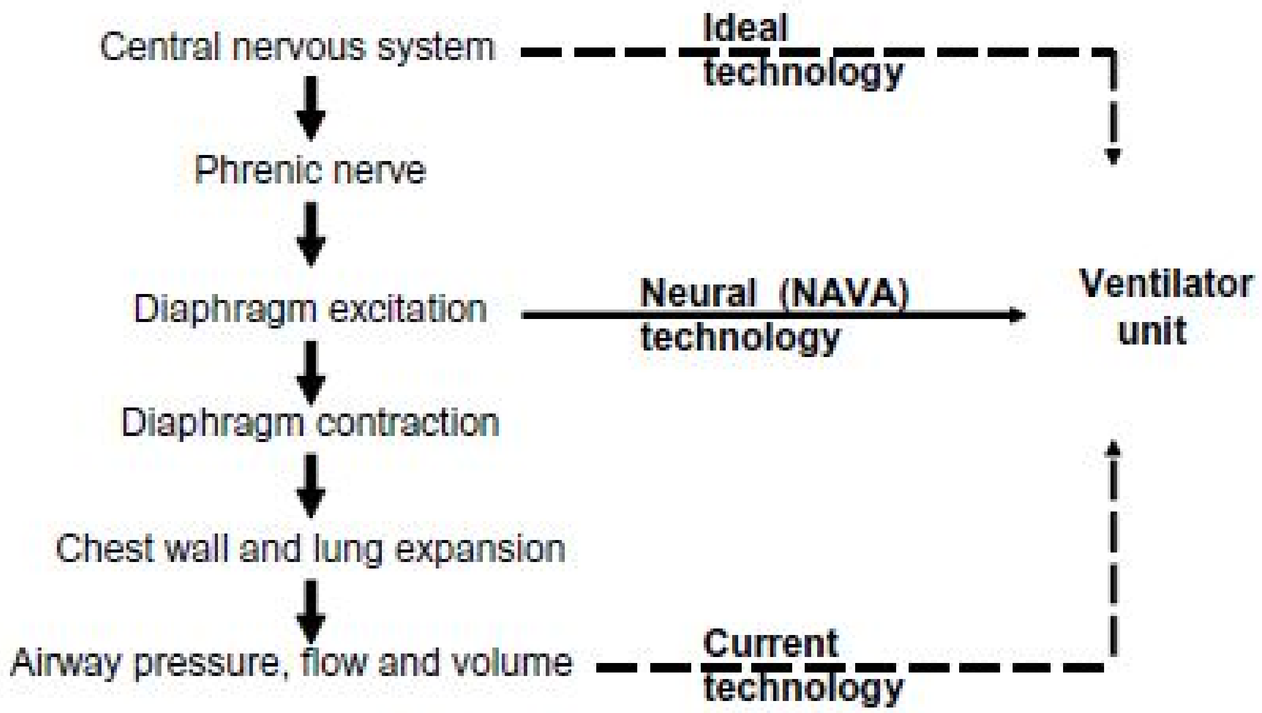


Photos courtesy of Dr. Magdy Younes

Physiologic Impact

- Ventilator cycle ends close to patient effort
  - Neural Ti = Ventilator Ti
  - Neural Te = Ventilator Te
- Level of assistance automatically adjusts to changes in effort intensity
- Allows for continuous monitoring of elastance and resistance and estimation of Pmus

Neuro-ventilator Coupling



http://www.respiratoryupdate.com/members/NAVA_Neurally_Adjusted_Ventilatory_Support.cfm

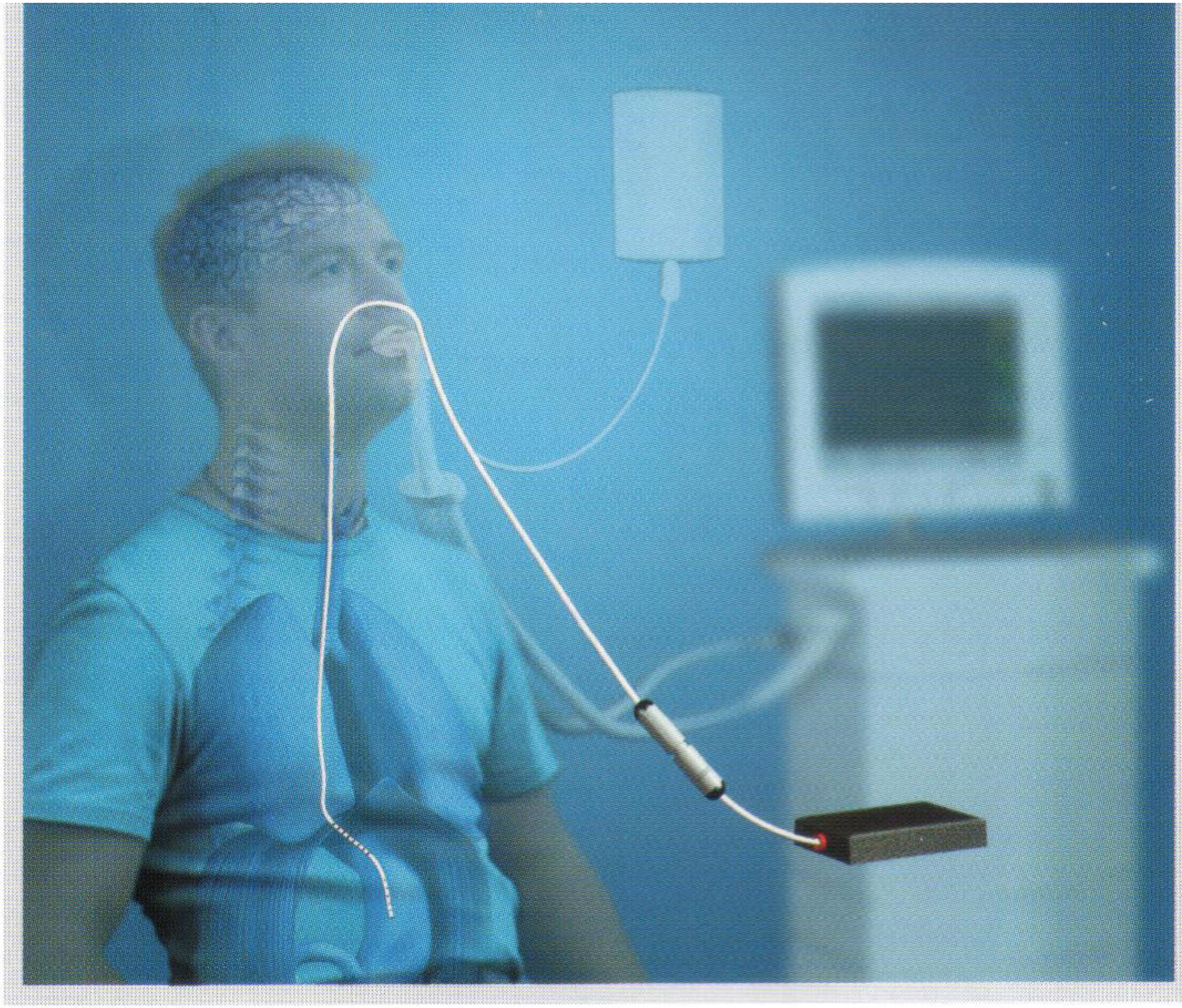
NAVA

Paw = NAVA level x EAdi

Paw – instantaneous

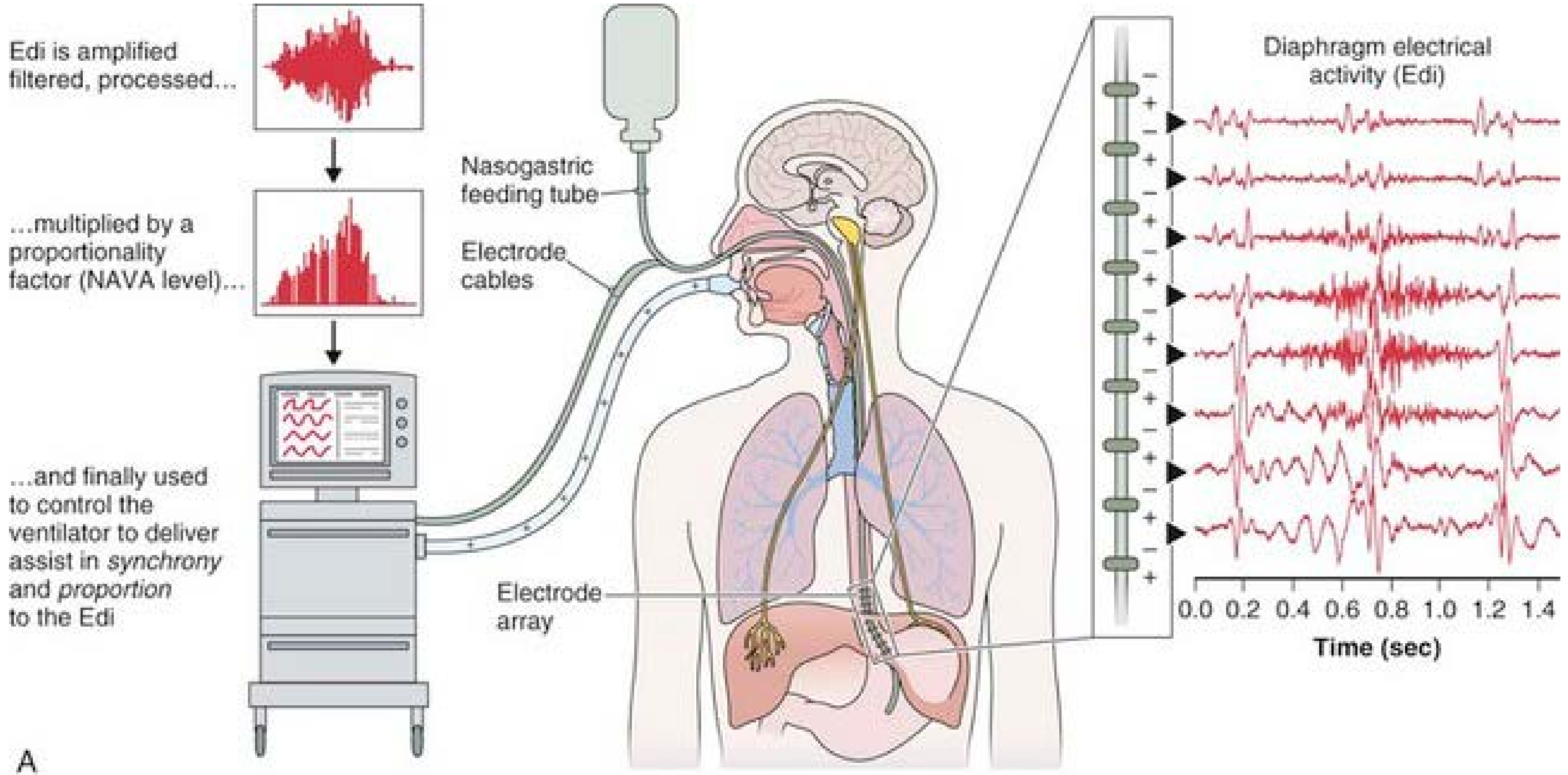
Eadi – instantaneous integral of the diaphragmatic electrical activity signal (ɥV)

NAVA level – cmH2O/ ɥV



NAVA senses activity in the diaphragm and responds by providing the requested level of ventilatory assist. The Edi signal is obtained by an electrode array mounted close to the distal tip of the Edi catheter. This catheter can also serve as a conventional nasogastric feeding tube.

NAVA



http://clinicalgate.com/invasive-mechanical-ventilation/

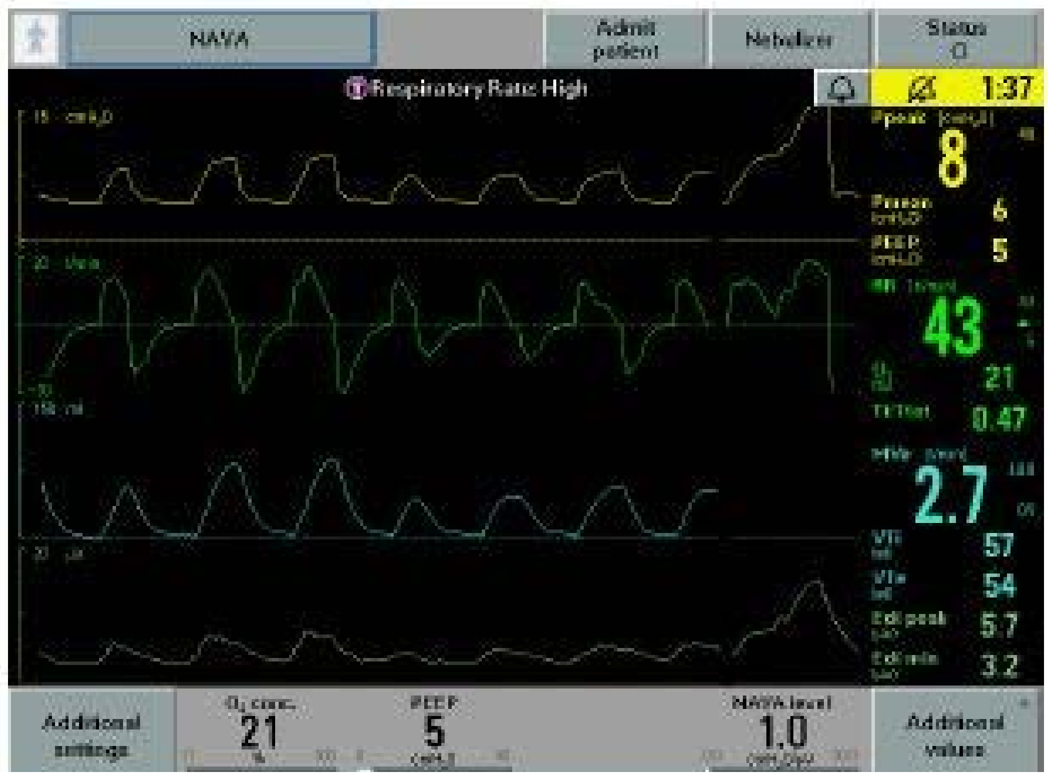
Invention to Commercialization

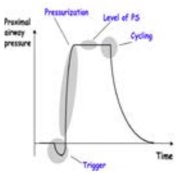
• Dr. Christer Sinderby

University of Toronto

Published “Neural control of mechanical ventilation in respiratory failure “ in 1999

License for patents belong to Maquet Critical Care SA, Sölna, Sweden





PSV

- Constant pressure from breath to breath
- Paw = constant
- Reduced natural variability of breathing pattern
- Can be associated with asynchrony or over-assistance

PAV

- Variable pressure proportional to the instantneous calculated Pmus
- Pappl + Pmus =Flow(R)+Vol(E)

NAVA

- Variable pressure proportional to the integral of the EAdi
- Paw = NAVA level x EAdi

Advantages of PAV and NAVA

- Improved synchronization
  - Reduced ineffective efforts
- Reduced risk of over-distention, (lower Vt and Pao)
- Reduced risk of over-ventilation
- Minimizes risk of diaphragm inactivity

Disadvantages of PAV

- In presence of PEEPi, ventilator provides support only during remaining duration of inspiratory effort post triggering

Disadvantages of NAVA

- Reliable positioning of the esophageal catheter
- PEEP, intra-abdominal pressure, body position may modify optimal position for catheter

PAV: Clinical studies

Result on PAV	Versus	Condition (n)	Duration	References
Improved synchrony	PSV	Acute respiratory failure (13, 50, 208)	< 48 hr	Bosma (1,2), Xirouchaki, Ranieri, Wysocki Georgopoulos, Younes
Averted risk of over-assistance, ↓Vt, ↓Ppeak	PSV	Mild, moderate ARDS (12)	< 1 hr	Kondili
Increased breathing pattern variability	PSV	Medical ICU (14,15)	< 1 hr	Varelmann, Ranieri
Improved cardiac index, Maintains gas exchange	PSV	Mild, moderate ARDS (12)	< 1 hr	Kondili
Improved sleep quality	PSV	Acute respiratory failure (14)	< 24 hr	Bosma(1)
Safe and tolerated	PSV/--	Acute respiratory failure (50, 56)	PSV Trial to extubation	Bosma(2), Carteaux

NAVA: Clinical studies

Result on NAVA	Versus	Condition (n)	Duration	References
Improved synchrony	PSV	Acute respiratory failure (14, 22, 14), ARDS (18, 11), COPD (14)	< 1 hr	Colombo, Wu, Terzi, Spahija, Piquilloud, Delisle
Averted risk of over-assistance	PSV	Acute respiratory failure (14, 14), ARDS (11), prolonged weaning (13)	< 1 hr	Colombo, Terzi, Vagheggini, Delisle (1), Delisle(2)
Increased breathing pattern variability	PSV	Mild ARDS (12), Post-operative patients (15), medical ICU (14)	< 24 hr	Schmidt, Coisel, Delisle(2)
Increased oxygenation, maintains gas exchange	PSV	Post-operative patients (15), COPD (14)	< 24 hr	Coisel, Spahija
Improved sleep quality	PSV	Acute respiratory failure (14)	< 24 hr	Delisle
Safe and tolerated		Acute respiratory failure (15, 12)	Failed SBT to extubation	Rozé, Rozé(2)

The PROMIZING Study

- CIHR-industry partnered operating grant
- 512 patients (Dec. 2015 – April 2018)
- 14 centres in Canada, France, Spain, Italy
- PAV+ set to target Pmus in normal range vs. PSV set to target RR and Vt in usual range
- From tolerating PSV to extubation
- Ventilator-free days at 21 days

The SENA Study

- A Randomized Controlled Trial of Conventional vs. Neurally Adjusted Ventilatory Assist in Difficult Weaning from Mechanical Ventilation (SENA)
- 200 patients (Feb. 2015 – Feb 2017)
- Sponsored by University Hospital, Bordeaux, France
- NAVA set to target 60% of Eadi max during SBT vs. PSV set to target RR 15-30 and Vt 6 mL/kg
- From first failed SBT to extubation x 48 hrs
- Duration of weaning

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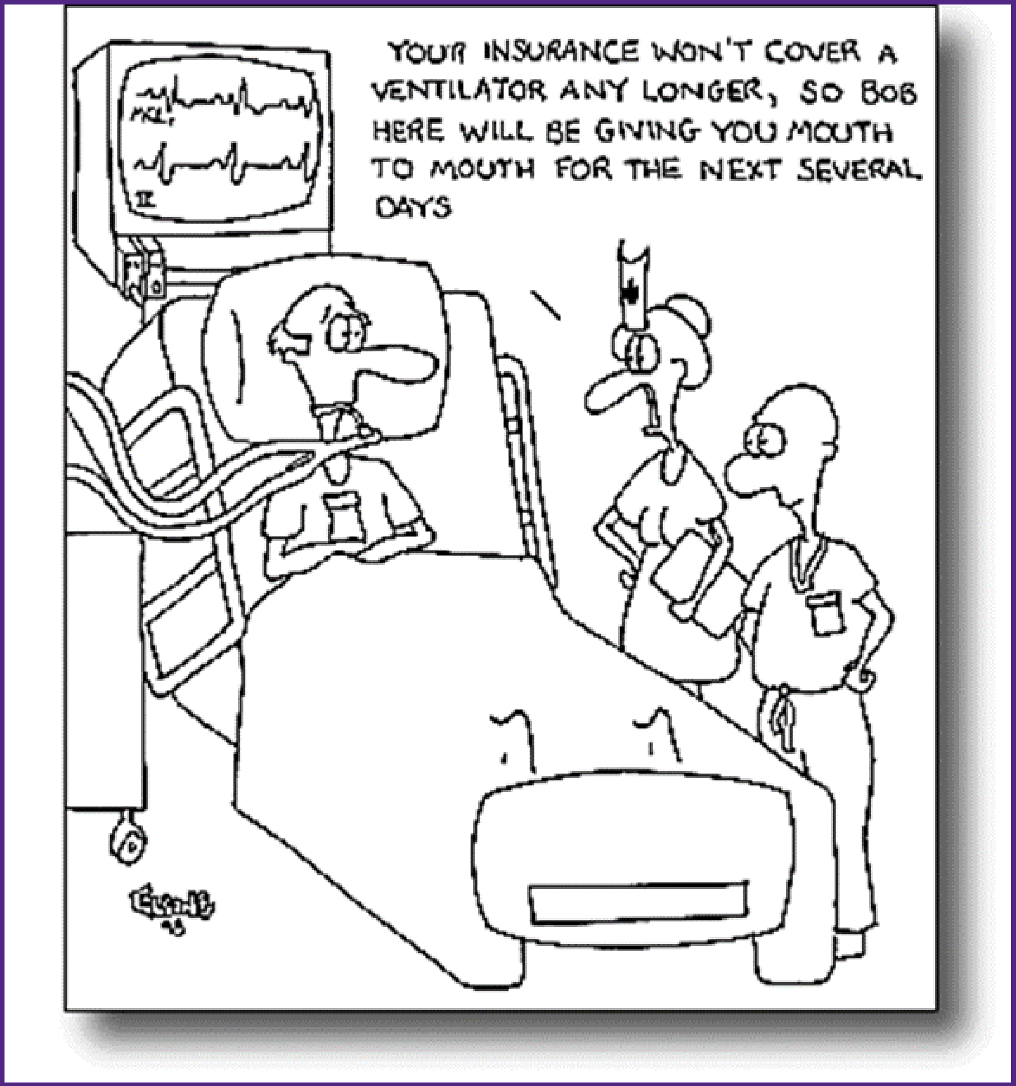
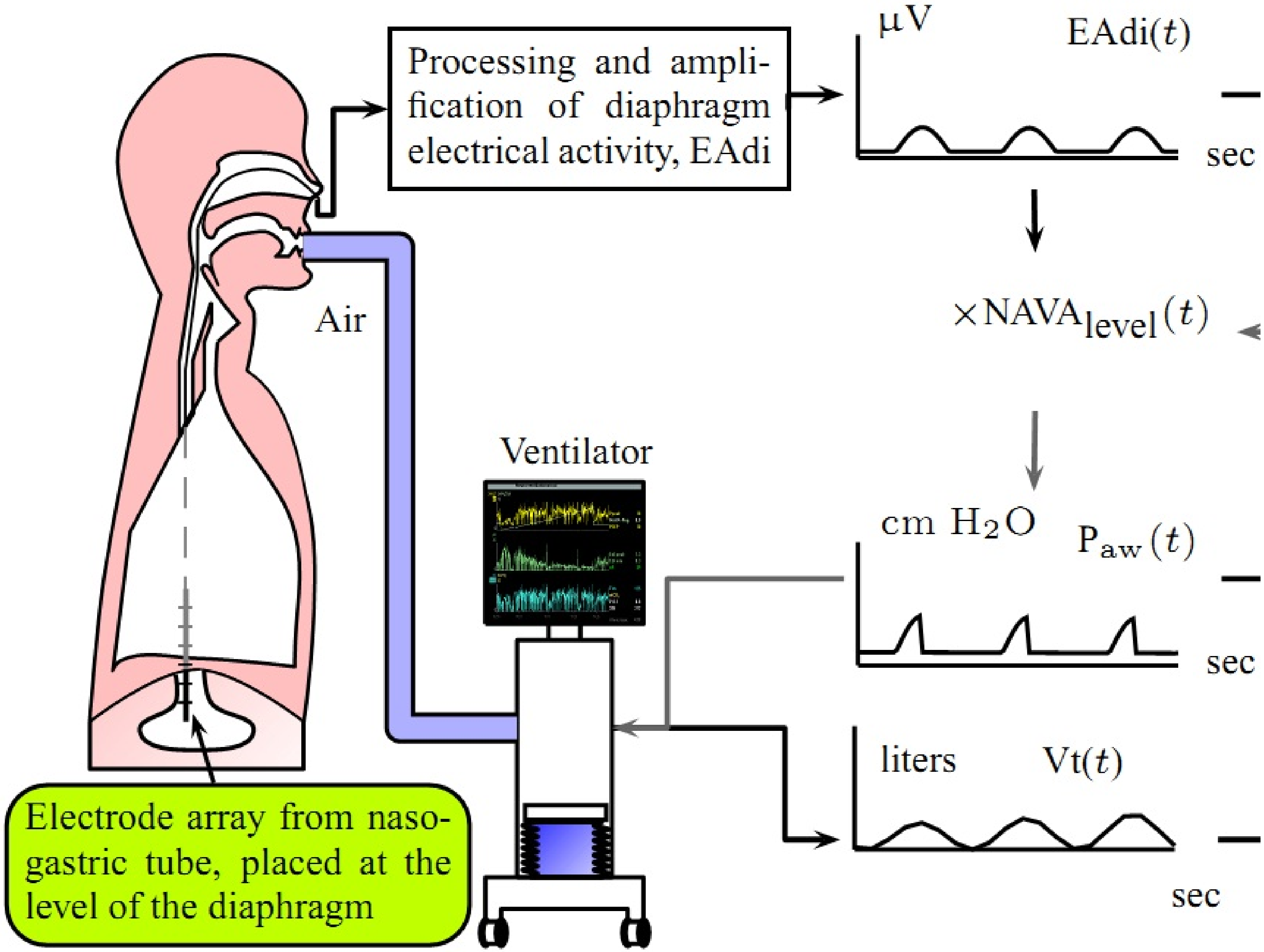

YOUR INSURANCE WON'T COVER A VENTILATOR ANY LONGER, SO BOB HERE WILL BE GIVING YOU MOUTH TO MOUTH FOR THE NEXT SEVERAL DAYS

Future Research: NAVA

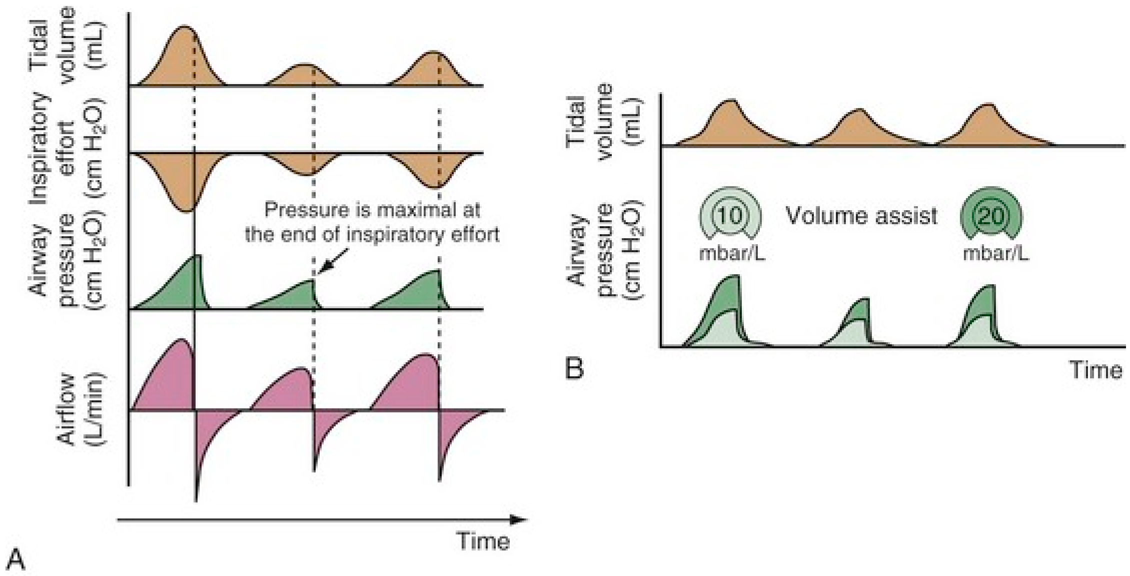
- What is the optimal method for setting NAVA level? What is an acceptable level of work of breathing?
- What is the optimal timing during the trajectory of critical illness to start NAVA?
- Is the esophageal probe effective over a long duration? When/ how often should it be repositioned?
- When is it NOT desirable to let the respiratory centres drive the ventilation?

		Controlled modes		Controlled/assisted combined modes				Assisted modes			Nonassisted spontaneous breathing
		VCV	PCV	SIMV	PRVC	VS	BiPAP, APRV	PSV	PAV	NAVA	CPAP
Termination of the breath is determined by	volume	✓	x	✓	✓	✓	x	x	x	x	x
	pressure	x	✓	✓	x	x	✓/x	x	x	x	x
	flow	x	x	x	x	x	x	✓	x	x	x
	time	x	(✓)/x	x	x	x	✓	x	x	x	x
Initiation of the breath by time/by patient effort		✓/✓	✓/✓	✓/✓	✓/✓	x/✓	✓/(✓)	x/✓	x/✓	x/✓	x/✓
Neurally triggered/cycled		x	x	x	x	x	x	x	x	✓	x
Predefined level of assist		x	x	✓	x	x	x	✓	x	x	x
Assist is proportional to the patient's respiratory effort		x	x	x	x	x	x	x	✓	✓	x

Breath Type		Classified By: Trigger	Limit	Cycle
NAVA	Spontaneous	PT *(Neurally, Press or $\dot{V}$)*	PL *(Neurally)*	PC *(Neurally)*
NAVA (PS)	Spontaneous	PT *(Press or $\dot{V}$)*	PL *(Press)*	PC *($\dot{V}$, P, Time)*
NAVA BACKUP	Mandatory	MT *(Time)*	ML *(Press)*	MC *(Time)*
	Assisted	PT *(Press or Vol)*	ML *(Press)*	MC *(Time)*



http://dimitriosververidis.blogspot.ca/



Tidal volume (mL)
Inspiratory effort (cm H_2O)
Airway pressure (cm H_2O)
Airflow (L/min)
Pressure is maximal at the end of inspiratory effort
Time
A
Tidal volume (mL)
Airway pressure (cm H_2O)
10
mbar/L
Volume assist
20
mbar/L
B
Time

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