

Physiology of NAVA

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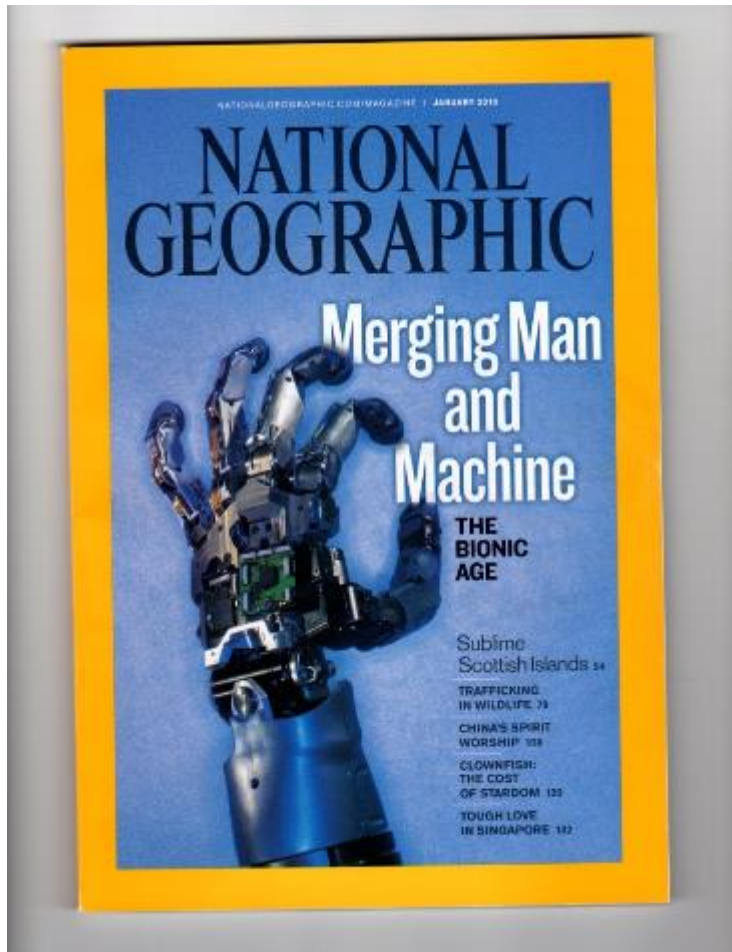
Disclosure

- | Consultant: Maquet Critical Care
- | Speakers Bureau: Maquet Critical Care
- | Stock Shareholder: Nothing to disclose
- | Employee: Nothing to disclose
- | Other (identify): Royalties on patents

The following disclosure was approved by University of Toronto and St-Michael's Hospital:

Dr. Beck has made inventions related to neural control of mechanical ventilation that are patented. The license for these patents belongs to Maquet Critical Care. Future commercial uses of this technology may provide financial benefit to Dr. Beck through royalties. Dr Beck owns 50% of Neurovent Research Inc (NVR). NVR is a research and development company that builds the equipment and catheters for research studies. NVR has a consulting agreement with Maquet Critical Care.

Neural Control of Artificial Muscles

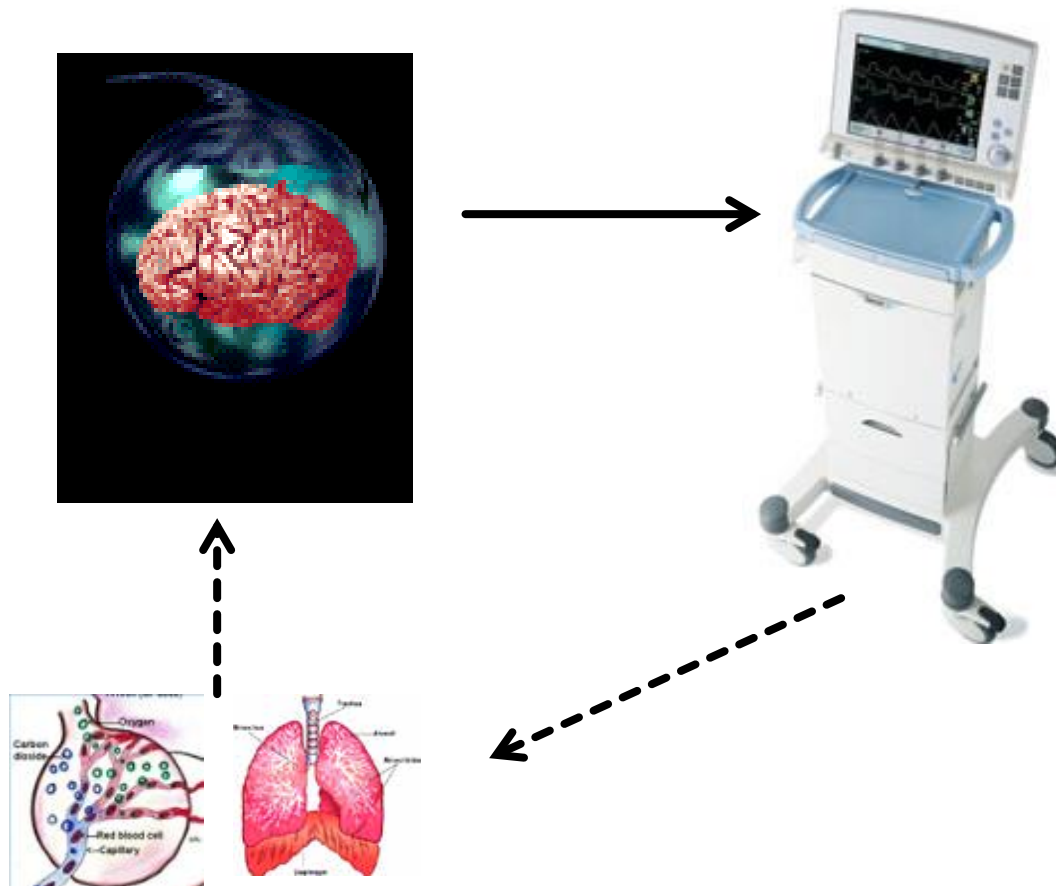


Jan 2010

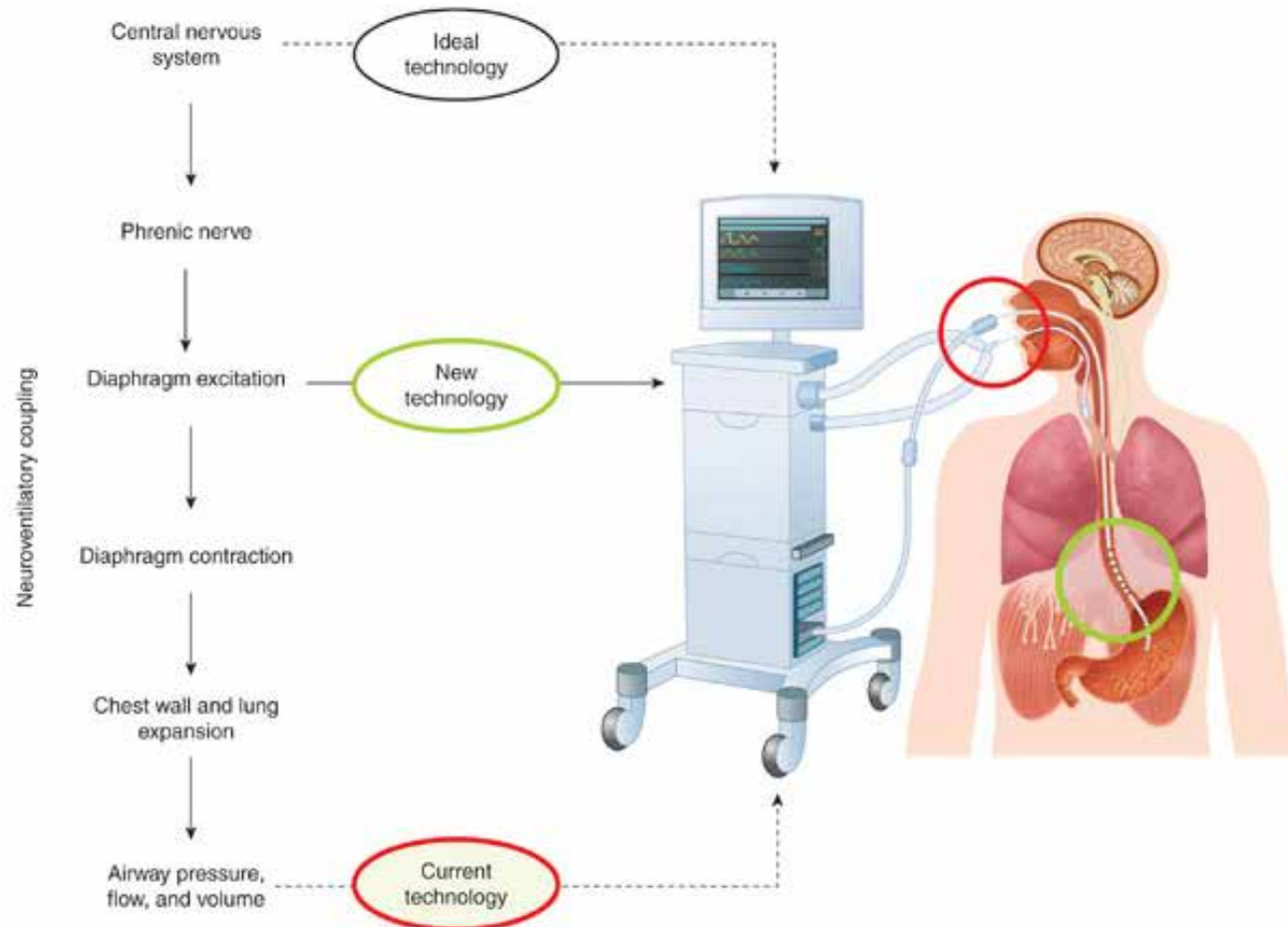


Time Magazine Jan 2008 (European Ed)

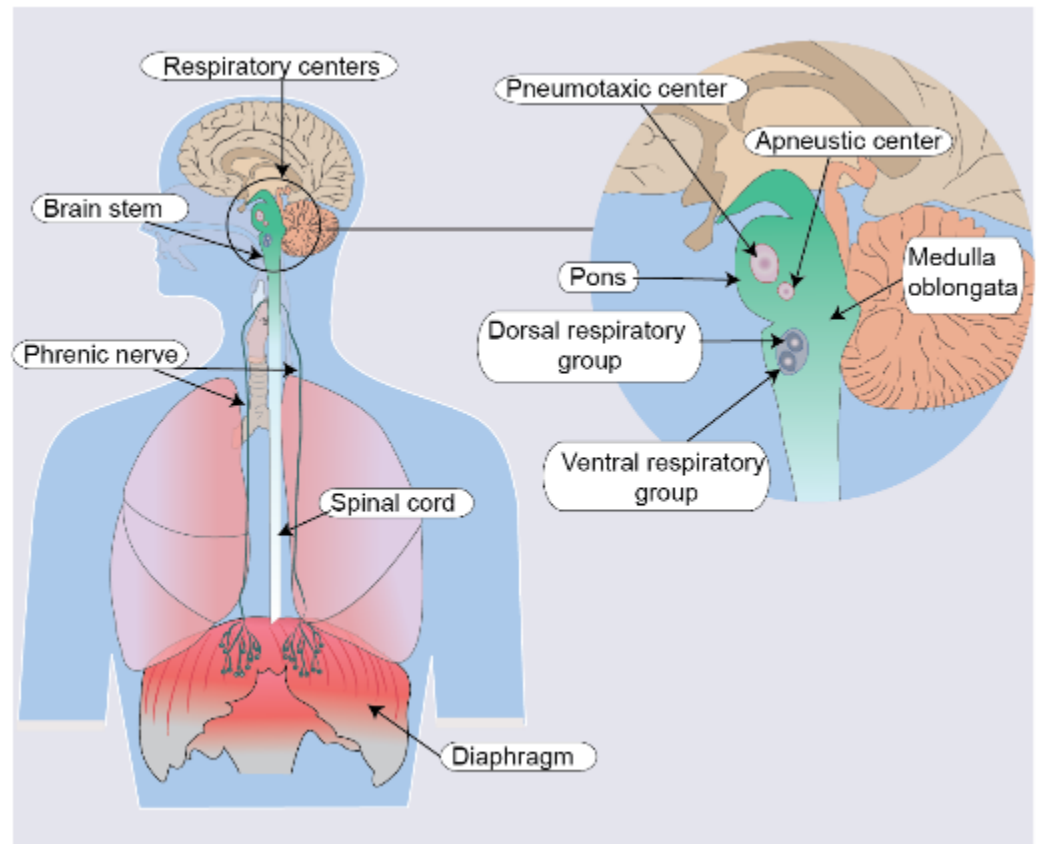
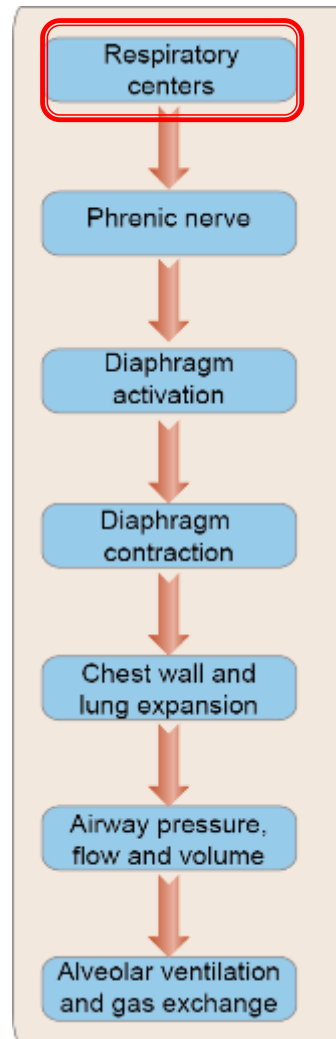
Neurally Controlled Mechanical Ventilation



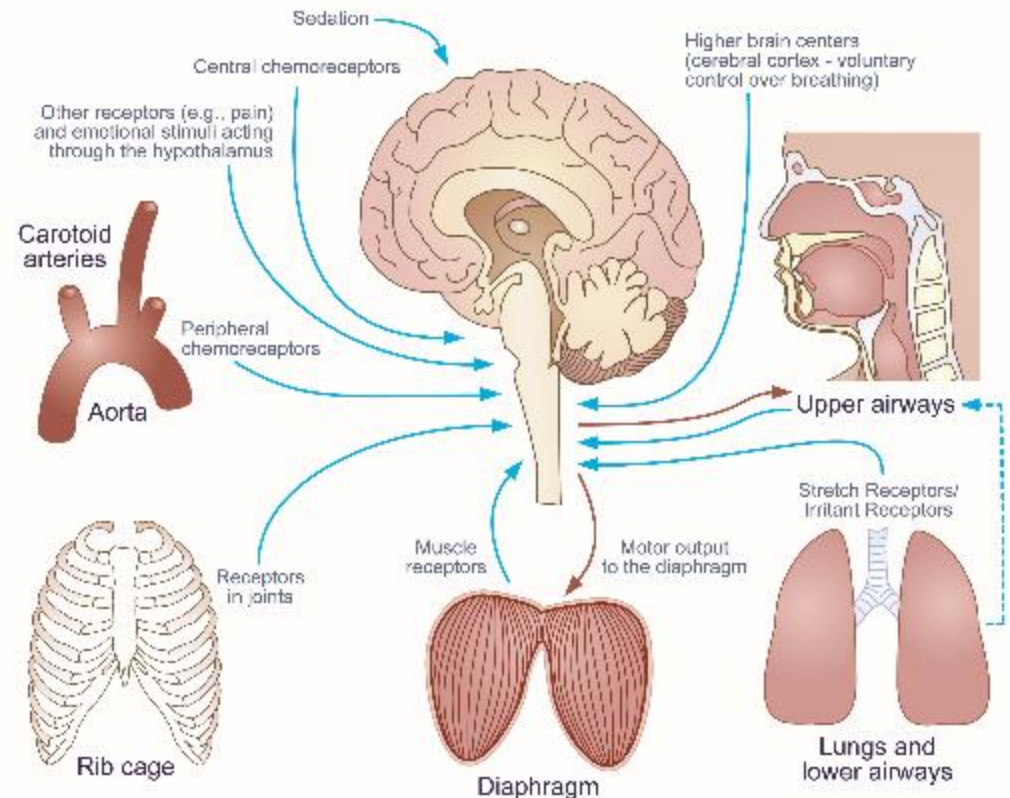
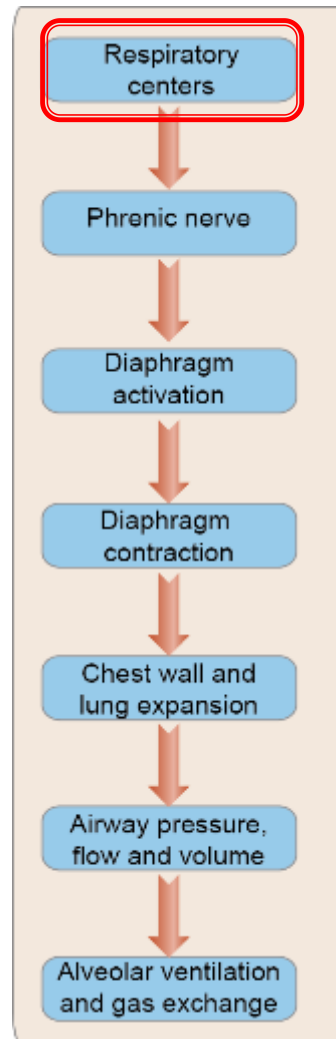
NAVA: What are we doing and what do we see?



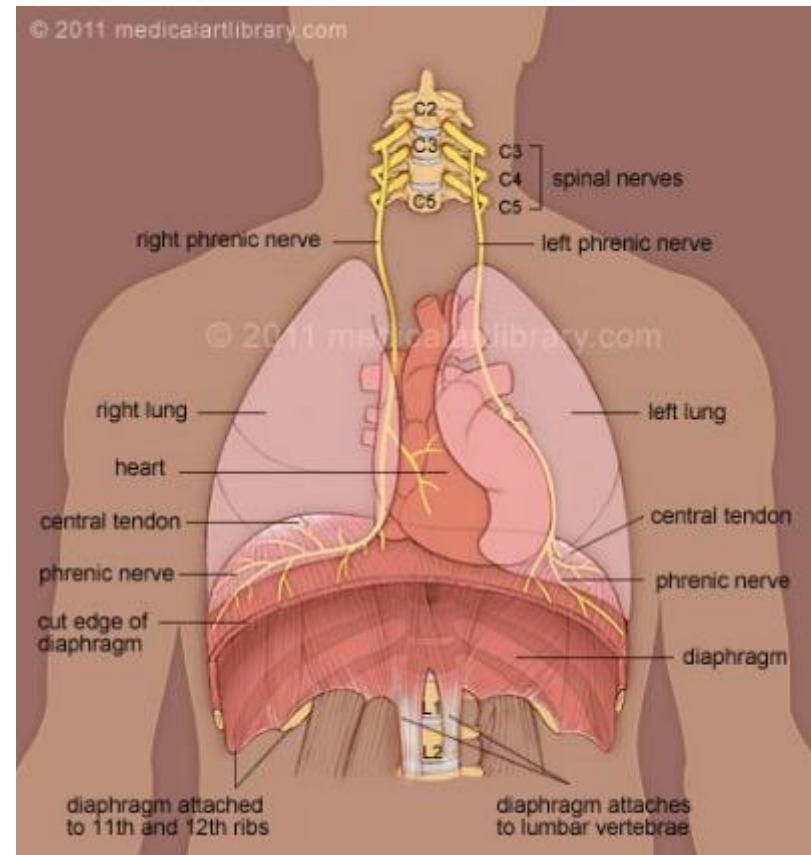
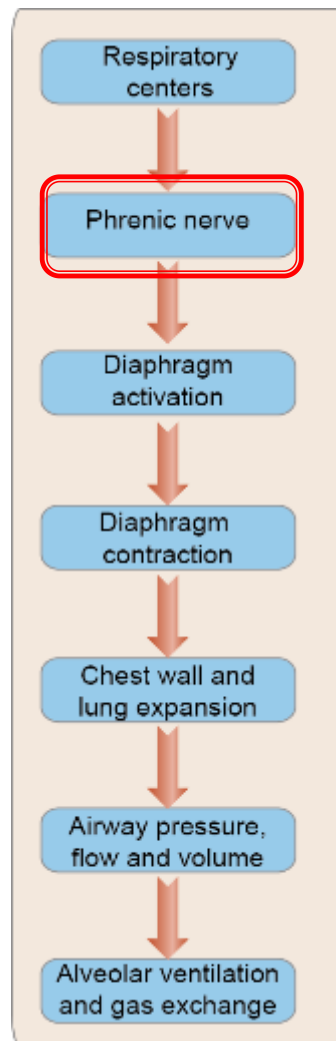
Spontaneous Breathing and the Respiratory Centers



Reflexes and Feedback to the Respiratory Centers

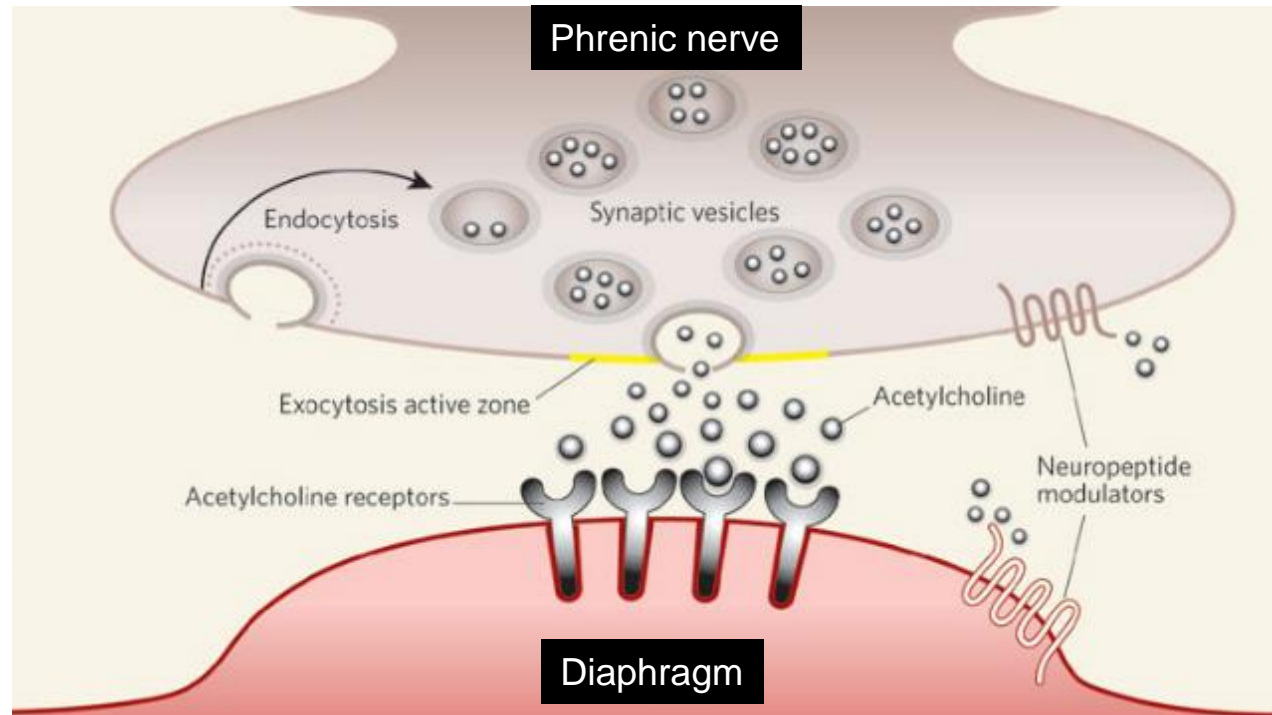
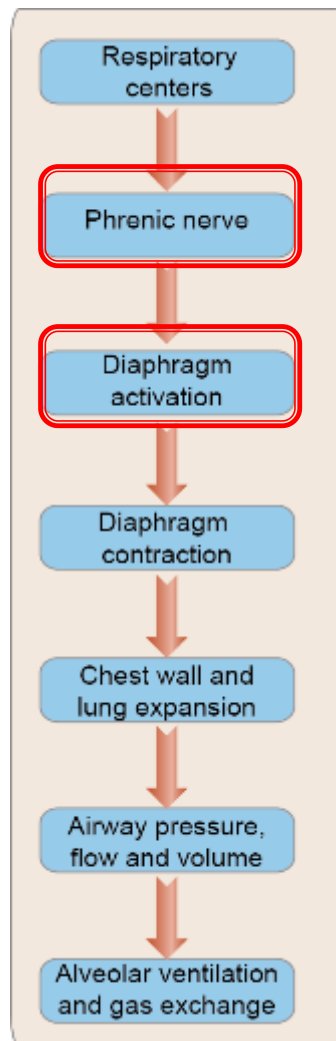


Phrenic Nerve Transmission

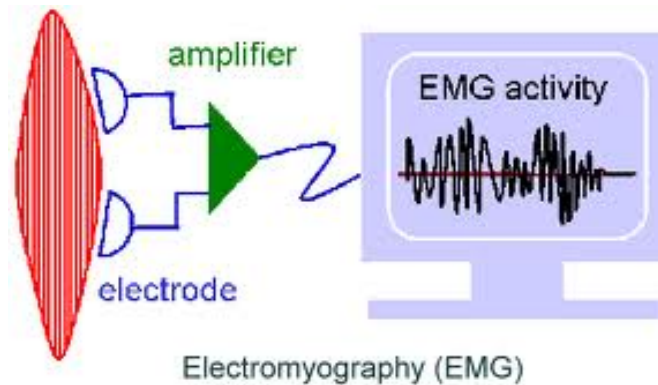
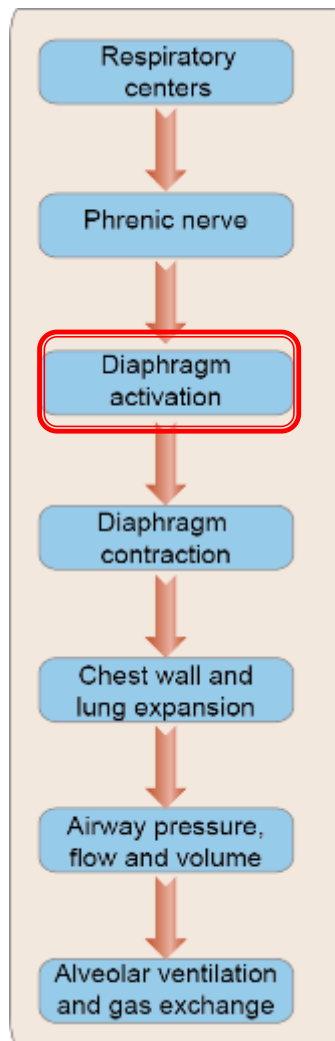


Stockmedicalart.com

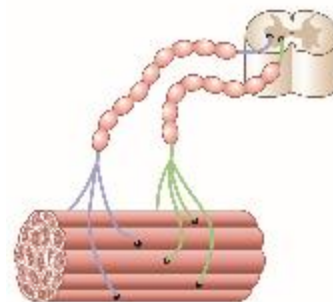
Neuromuscular Transmission



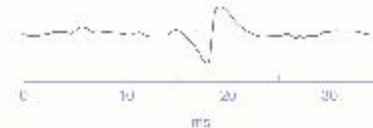
EMG of Skeletal Muscle



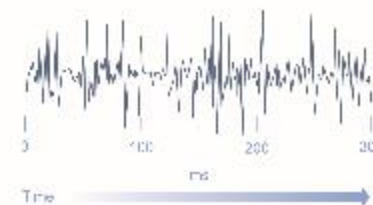
Note: EMG = EAdi = Edi



Single motor unit action potential

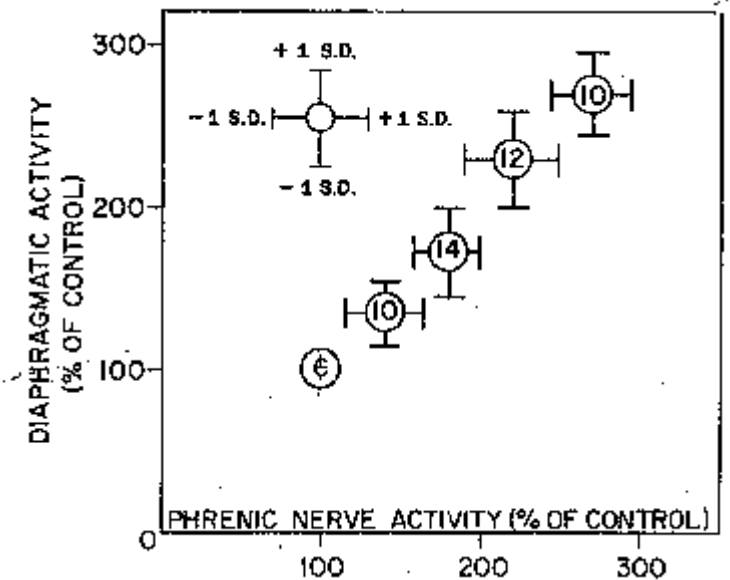
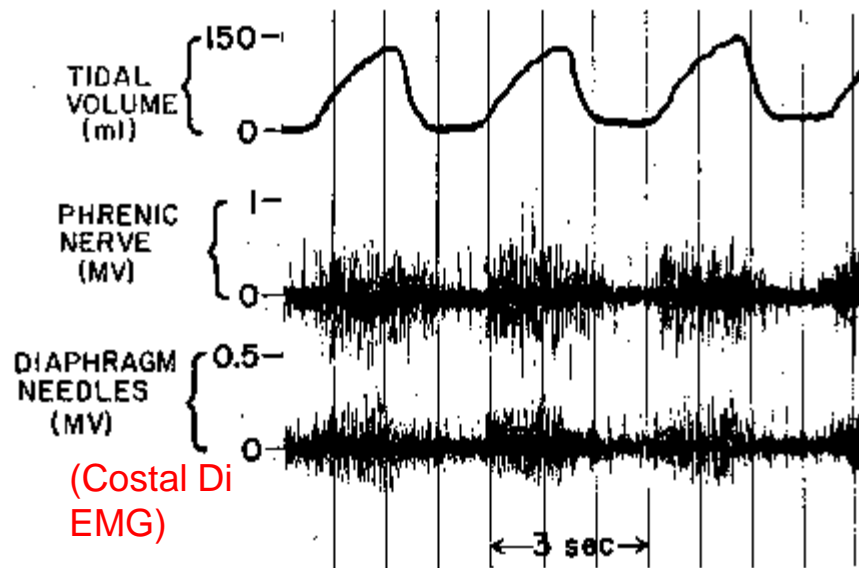


Multiple motor unit interference pattern

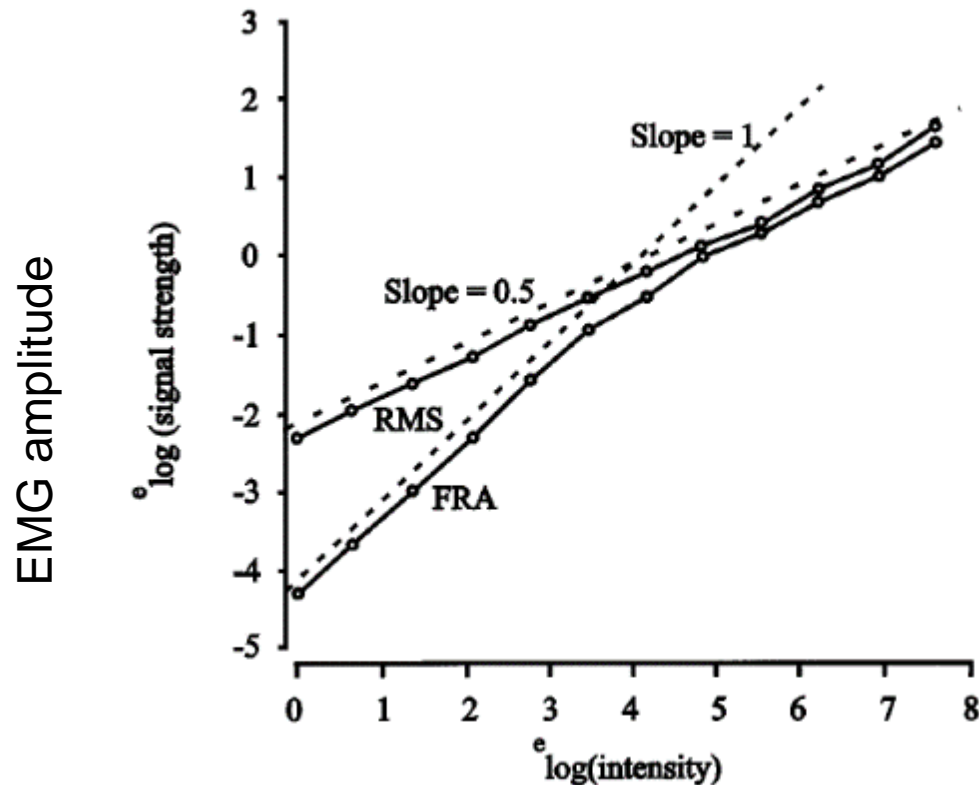


Principles and Practice of Mechanical Ventilation, M Tobin Ed. 2012

Phrenic Nerve-EMG Relationship

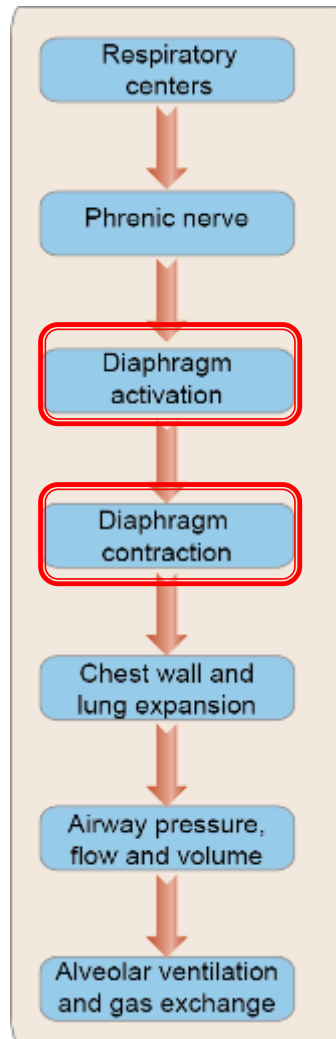


EMG-Muscle Activation Relationship

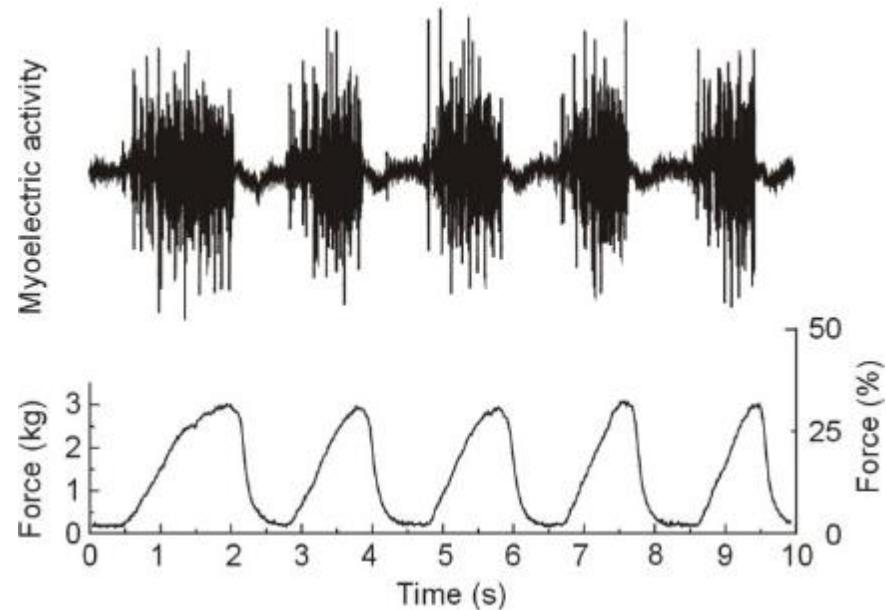


Diaphragm activation (recruitment and firing rate)

EMG-Force of the Diaphragm

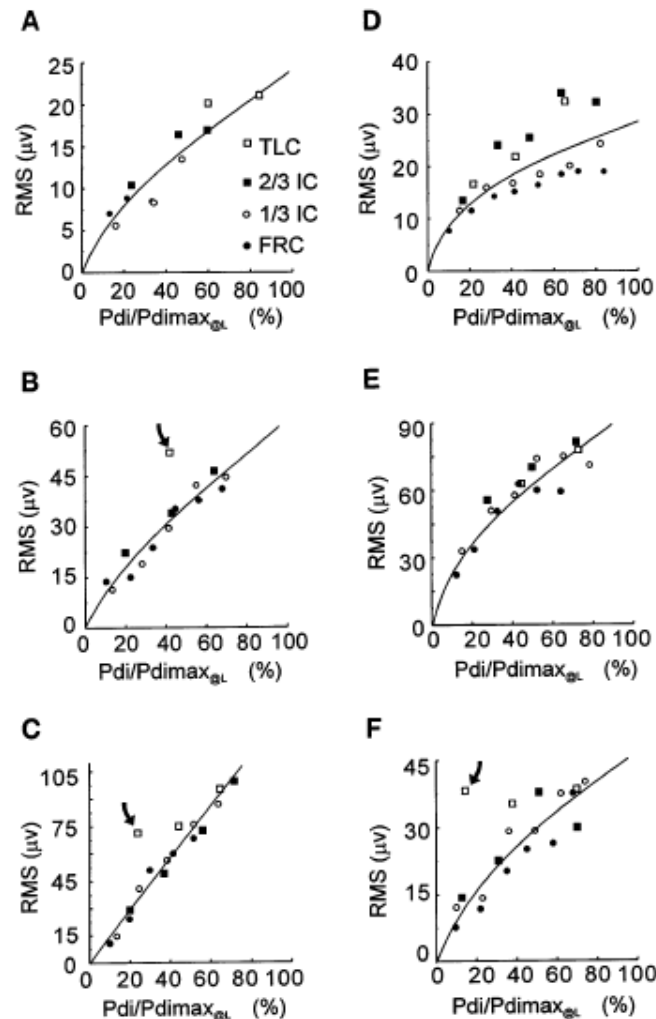
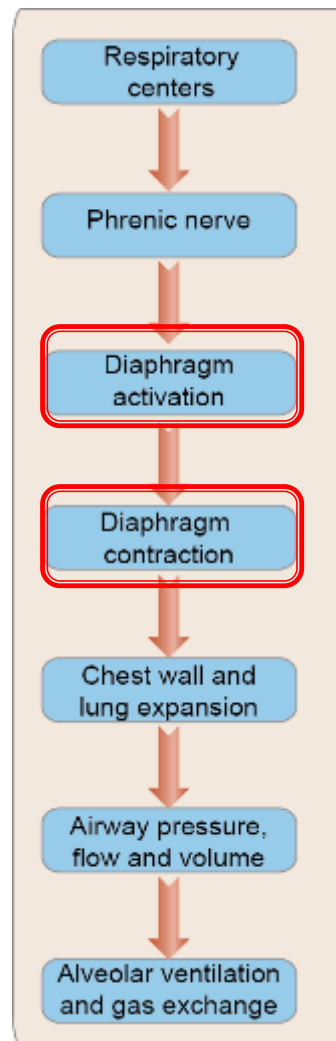


Spontaneous activity of the costal diaphragm

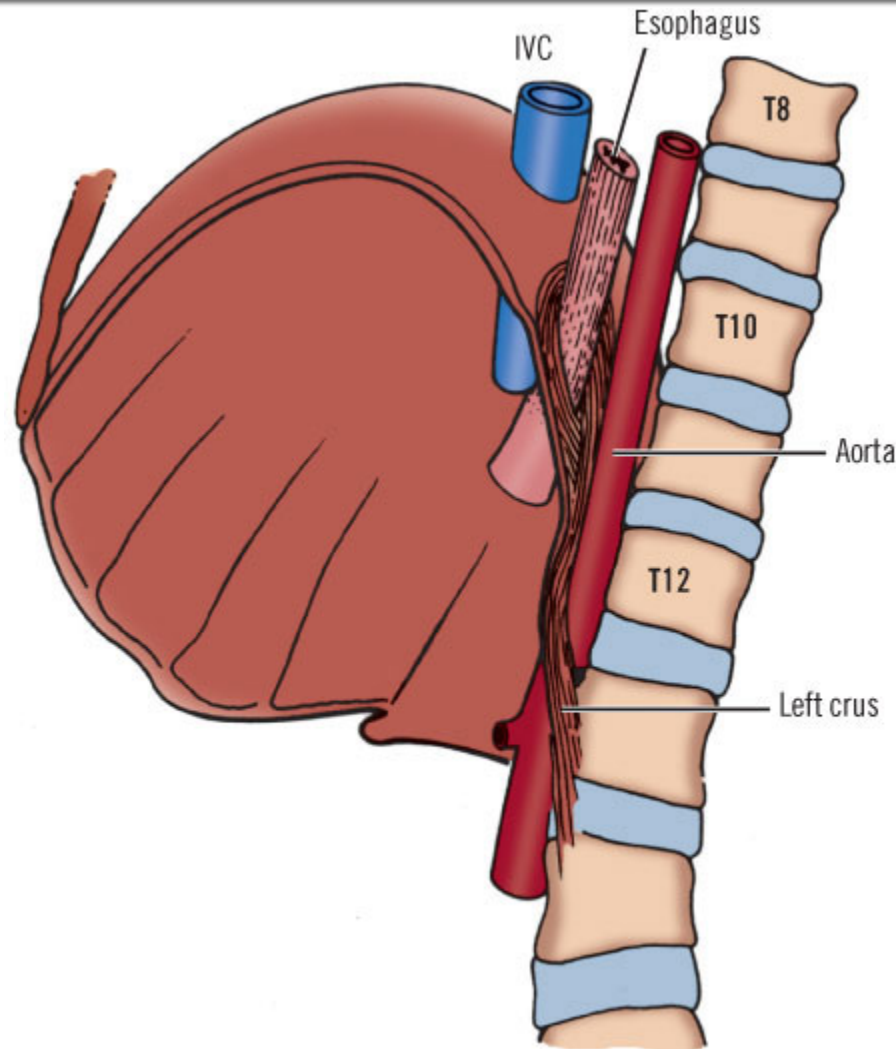


Sinderby, 1995, unpublished

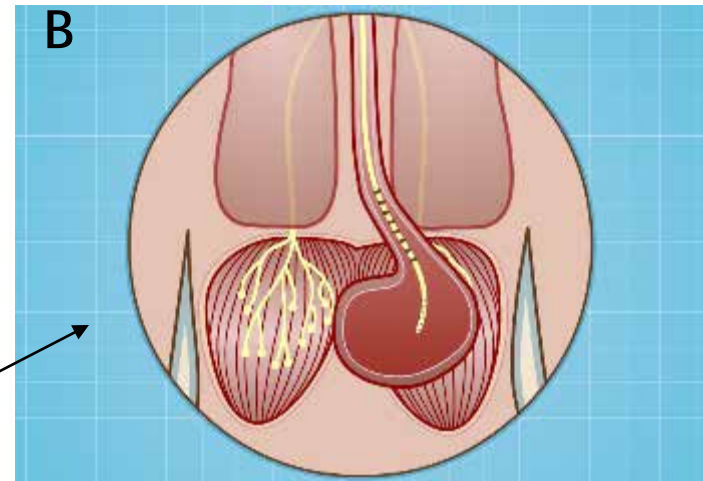
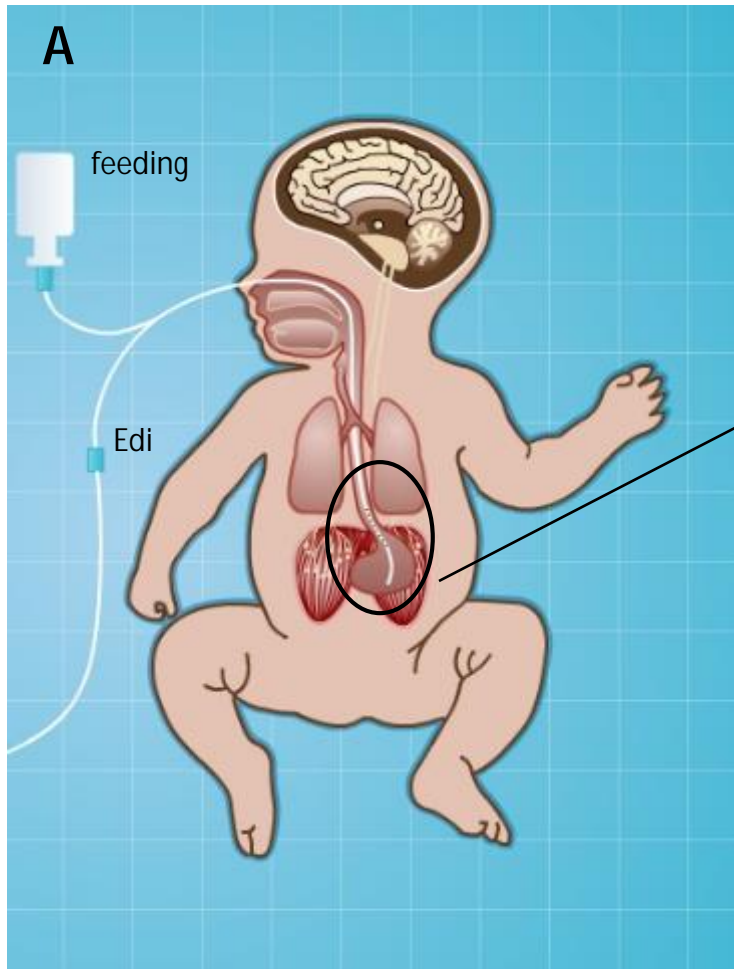
EAdi-Force of the Diaphragm



How to Measure Diaphragm EMG in Humans?



Measuring Diaphragm EMG = Edi



Electrode Positioning

- i NEX
- i Calculate prediction
- i Insert to prediction
- i Positioning window (verification)
- i Secure and record final position

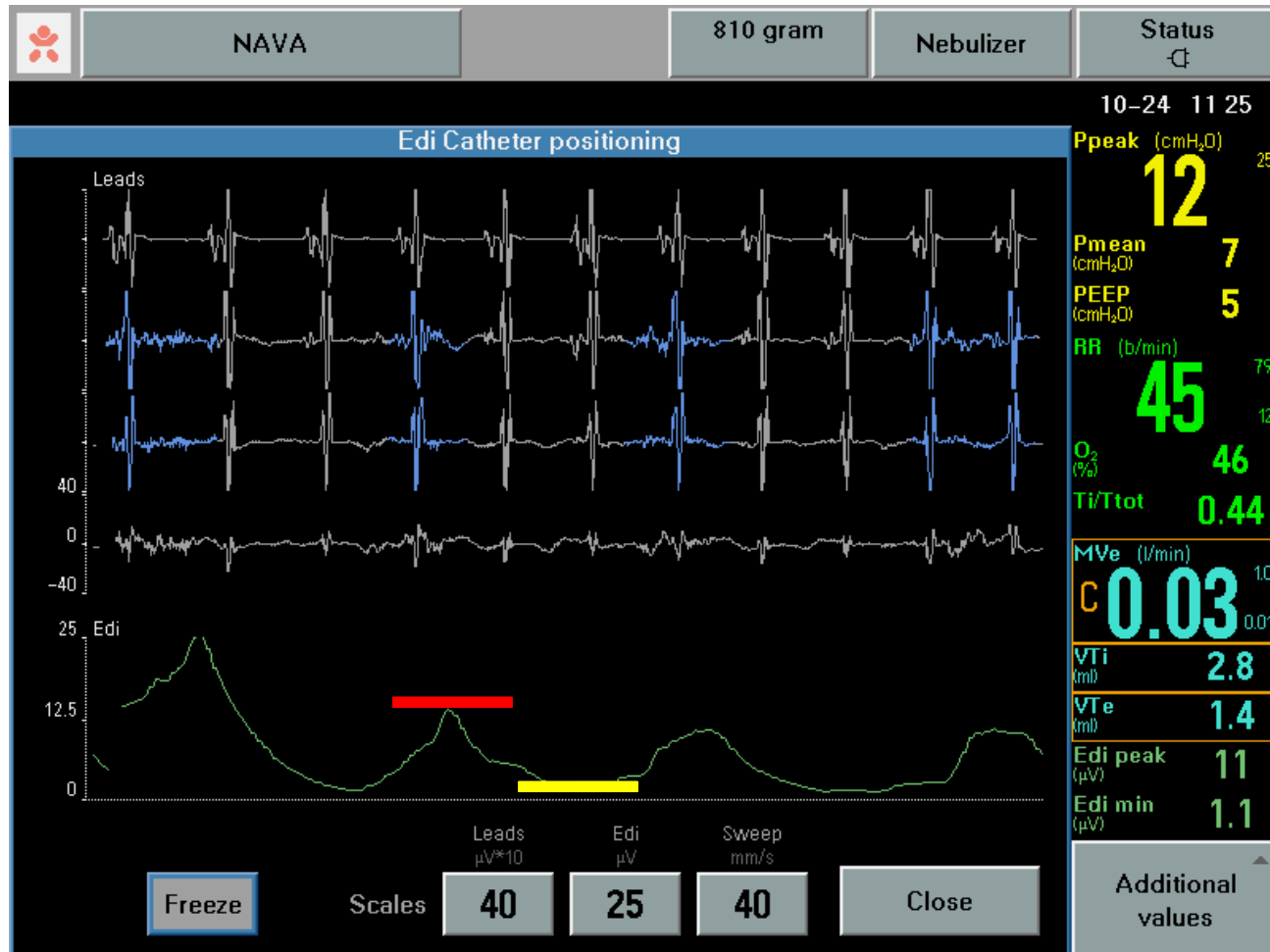
Validation of Electrode Positioning

- Barwing J, Ambold M, Linden N, Quintel M, Moerer O. Evaluation of the catheter positioning for neurally adjusted ventilatory assist. Intensive Care Med. 2009 Oct;35(10):1809-14
- Green ML, Walsh BK, Wolf GK, Arnold JH. Electrocardiographic guidance for the placement of gastric feeding tubes: a pediatric case series. Respir Care. 2011 Apr;56(4):467-71
- Barwing J, Pedroni C, Quintel M, Moerer O. Influence of body position, PEEP and intra-abdominal pressure on the catheter positioning for neurally adjusted ventilatory assist. Intensive Care Med. 2011 Dec;37(12):2041-5.
- Anita Duyndam, Bas SP Bol, Andre´ Kroon, Dick Tibboel and Erwin Ista. Neurally adjusted ventilatory assist: assessing the comfort and feasibility of use in neonates and children. Nursing in Crit Care. In Press, Dec 2012

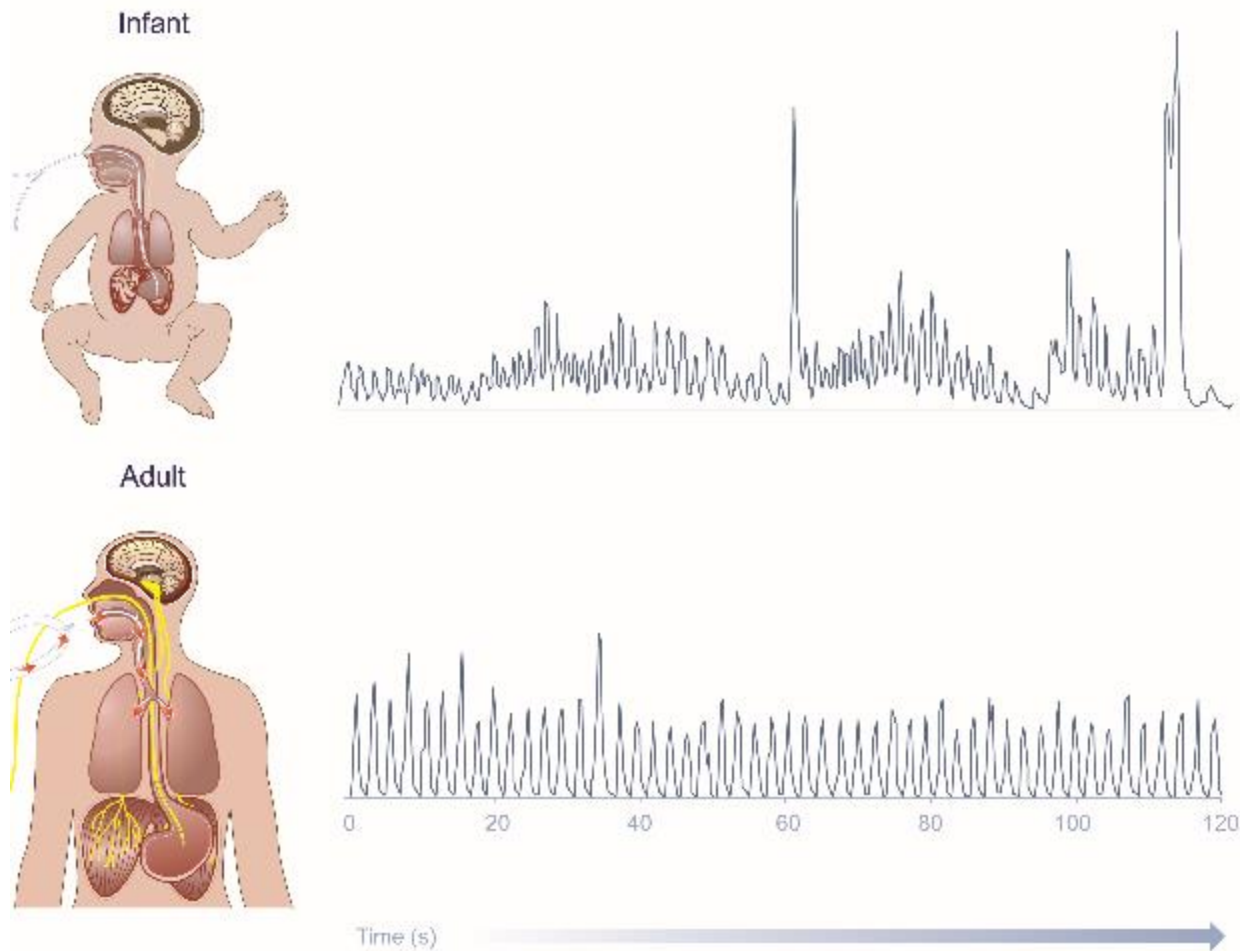
Edi waveform

4 leads

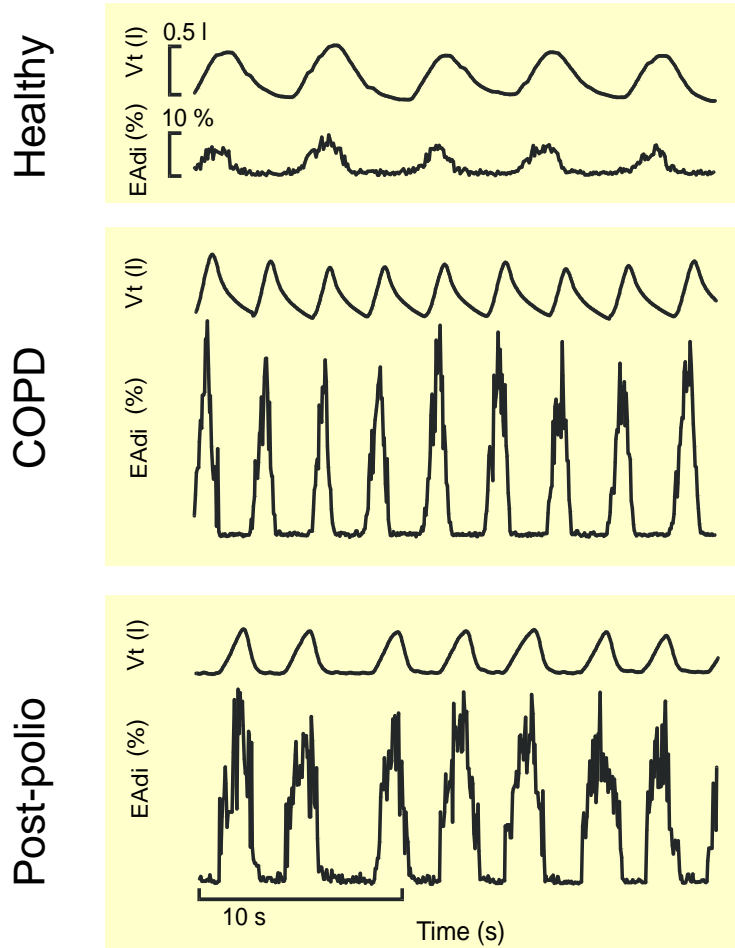
Edi



Edi in Infants and Adult



Edi_{peak}



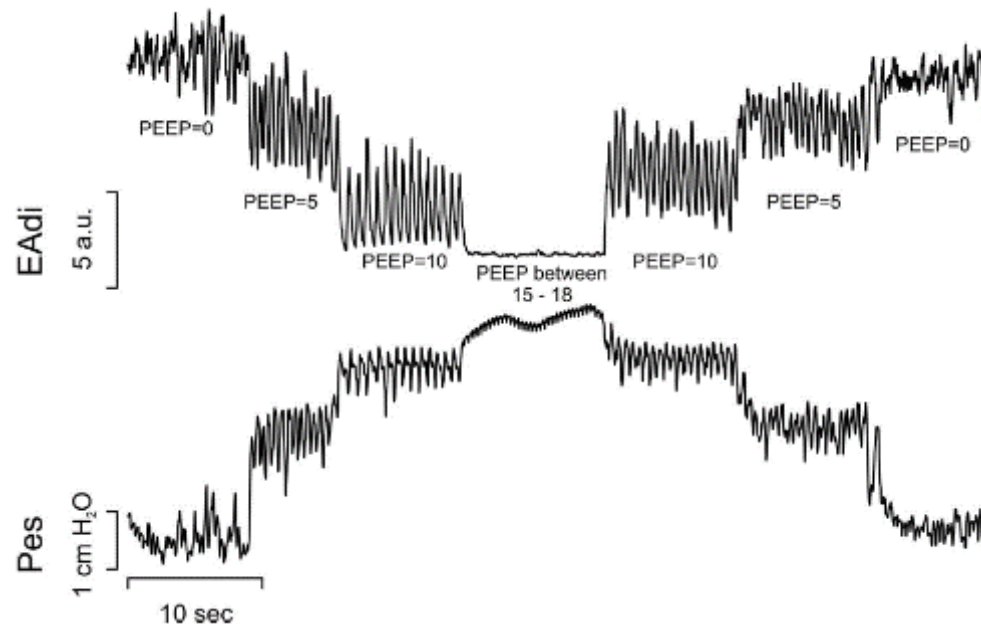
- Reduced level of assist
- Increased Respiratory Load
- Weakness of Diaphragm
- Increased CO₂
- Reduced sedation

Edi_{min}

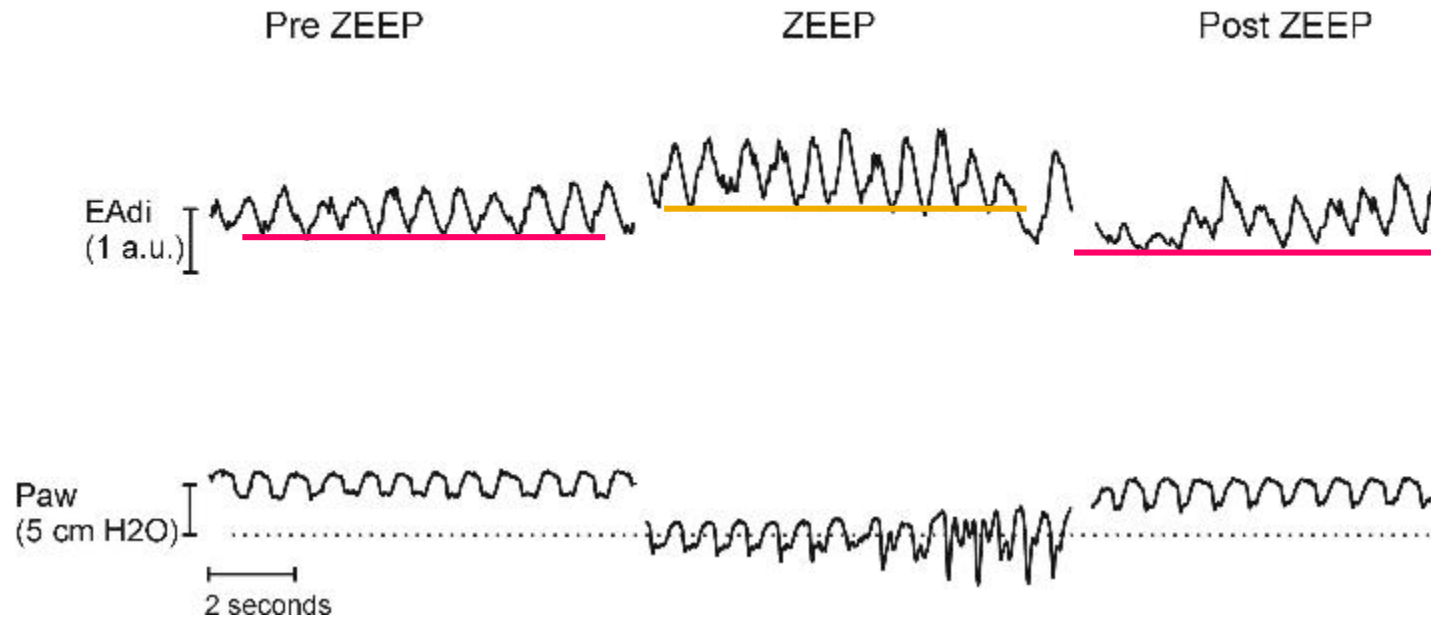
Influence of neurally adjusted ventilatory assist and positive end-expiratory pressure on breathing pattern in rabbits with acute lung injury*

Jean-Christophe Allo, MD; Jennifer C. Beck, PhD; Lukas Brander, MD; Fabrice Brunet, MD; Arthur S. Slutsky, MD; Christer A. Sinderby, PhD

Crit Care Med 2006 Vol. 34, No. 12



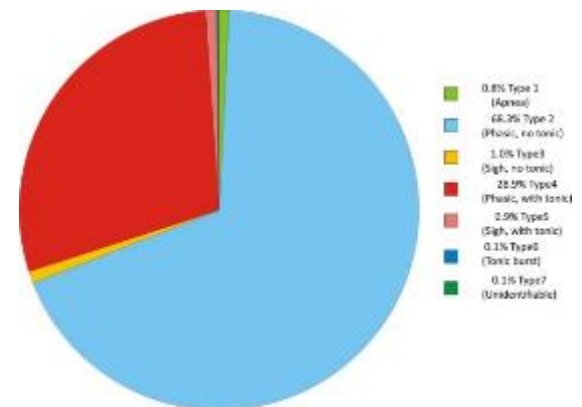
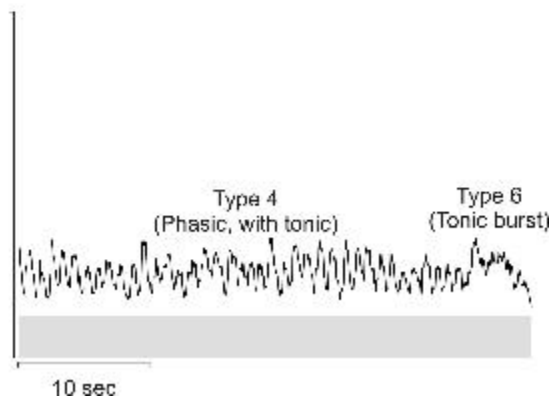
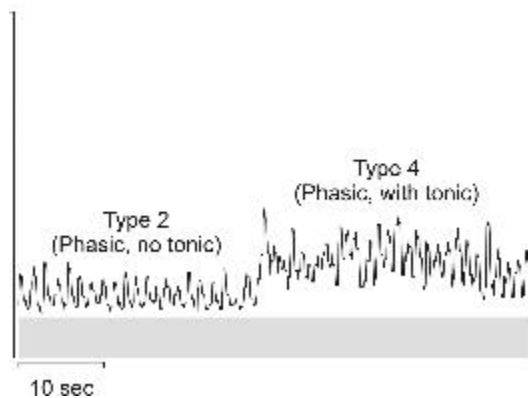
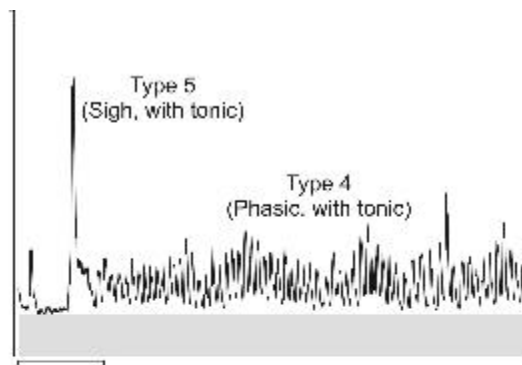
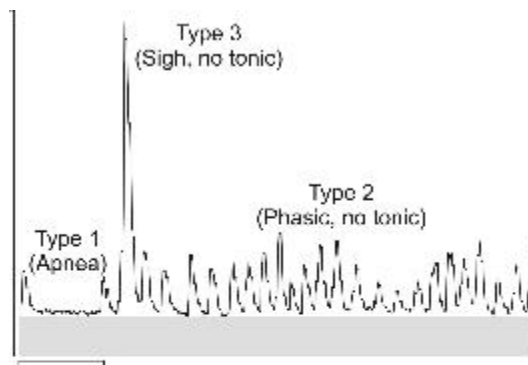
Edi_{min}



Emeriaud et al, Ped Res, 2006

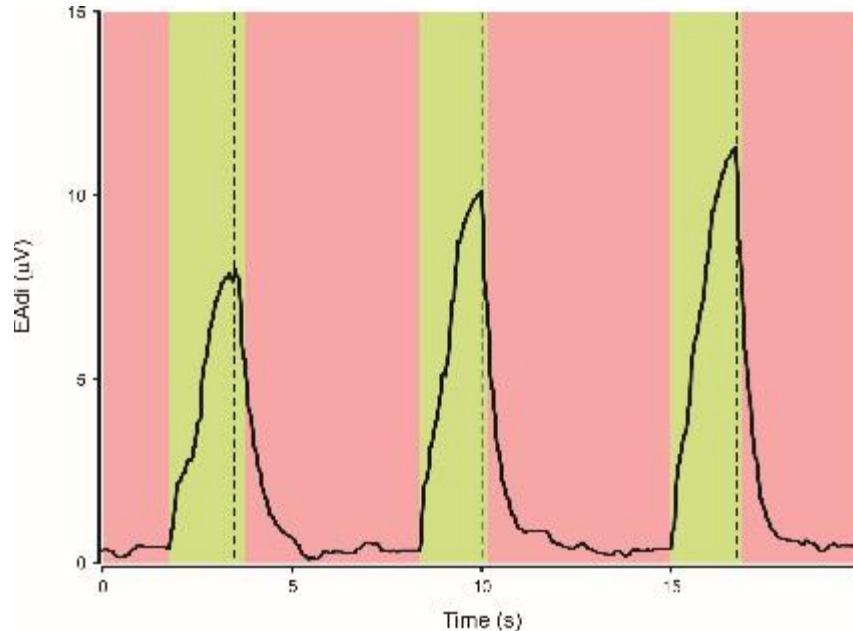
- De-recruitment below FRC
- Liquid/edema in the lung
- ??

Elevated Edi_{min} in Preterms

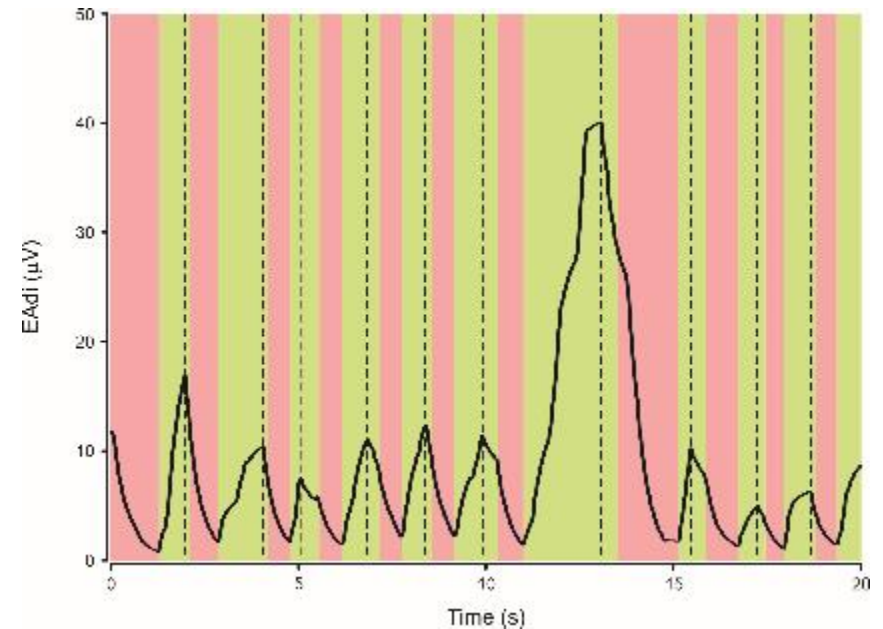


Neural timings (Nti, Nte, Nrr)

Adult



Infant



The Controversy of Neural Ti

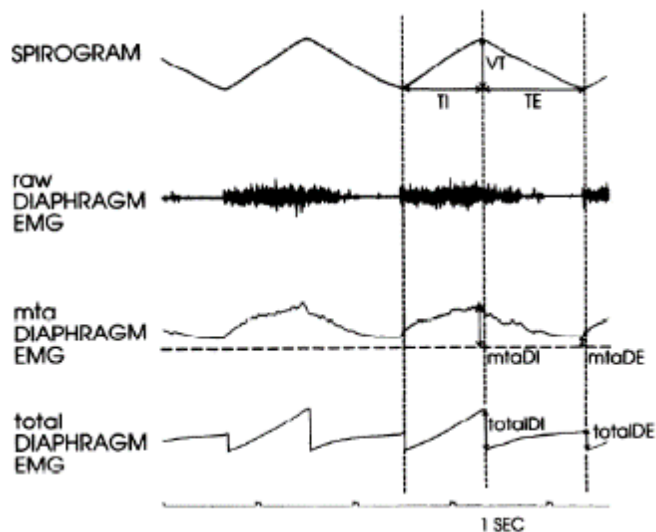


FIG. 1. Representative spirogram and EMG recordings in diaphragm. Raw, after conventional integration by moving time average (mta EMG) and after a separate integration of summed EMG activity during inspiration and expiration (total EMG). VT, tidal volume; Ti, inspiratory time; Te, expiratory time; DI and DE, diaphragmatic activity at end of inspiration and end of expiration, respectively. Procedures used to derive and measure records are in METHODS.

Bonora JAP 1994

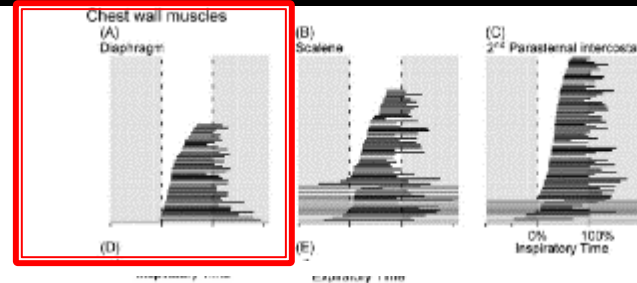
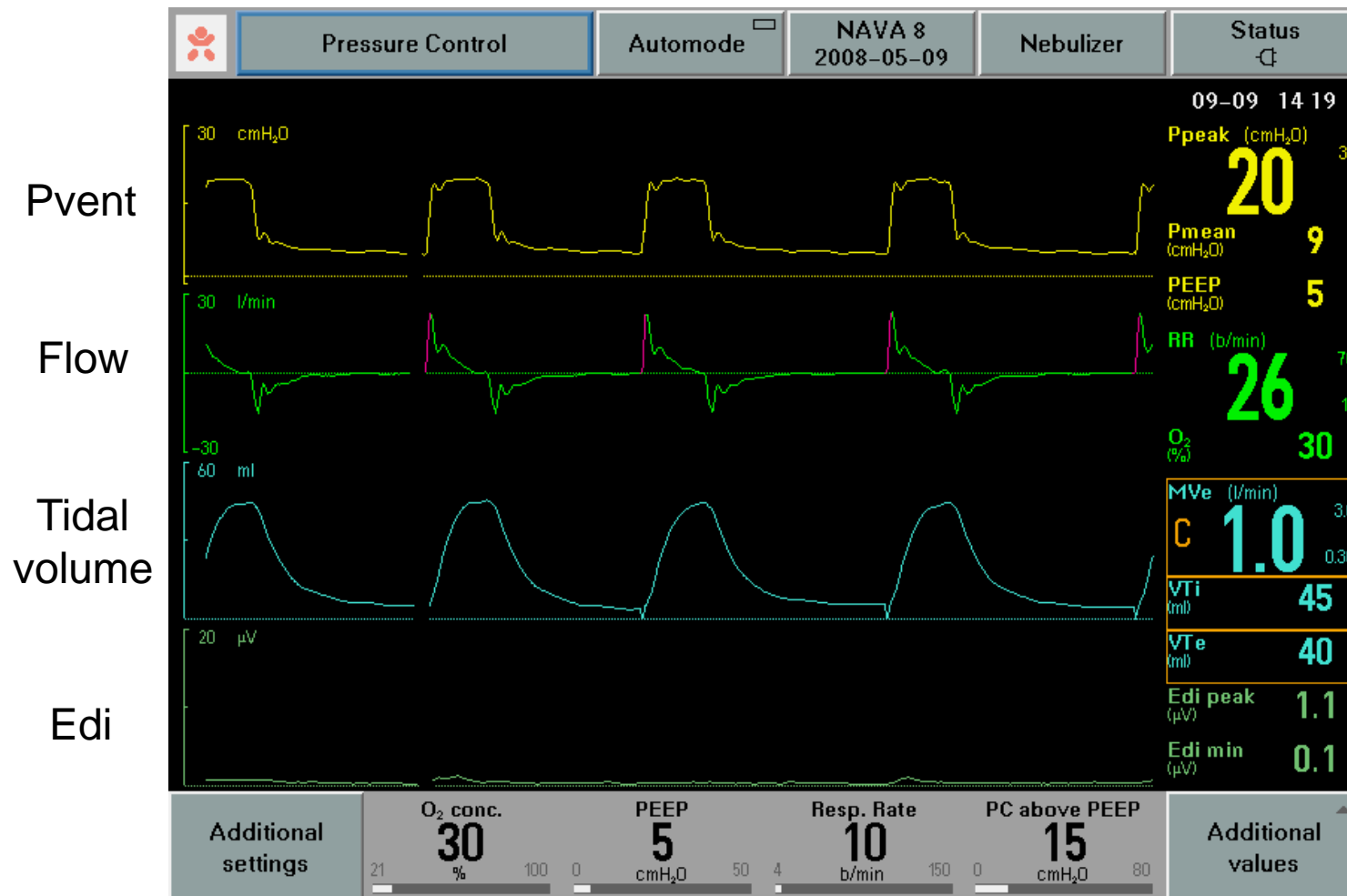


Fig. 2. Timing of the discharge of motor units in six human inspiratory muscles. Panels A-F show the firing time for each single motor unit recorded from five different chest wall inspiratory muscles (upper panels A-E) and one upper airway muscle (genioglossus, panel F) during quiet breathing, relative to the time of inspiration or expiration (expiratory time is shaded grey). For each unit, the thick horizontal line represents the time that the firing frequency increases in the inspiratory or expiratory phase of respiration. The thin horizontal line indicates tonic firing of the motor unit at other times. The units are ordered relative to their onset time. Physically firing units during inspiration (IP) or expiration (EP) are shown on top, tonically firing units that increased their discharge during either inspiration (TI) or expiration (ET) are shown beneath. Tonically firing units that did not increase their firing in time with respiration (TT) are also shown. The proportion of tonically active units (TT, ET and TI) is higher for genioglossus (panel F) than the chest wall muscles. TT, EP and ET units have not been observed in the inspiratory muscles that act on the chest wall (panels A-E). The different slope of the onset times for the population of motor units for each muscle (e.g. panel A compared to panels E and F) represents different inspiratory drive to each muscle that may be controlled at the motoneurons or at a higher level. Adapted from Subissi et al. (2006, 2007) used with permission.

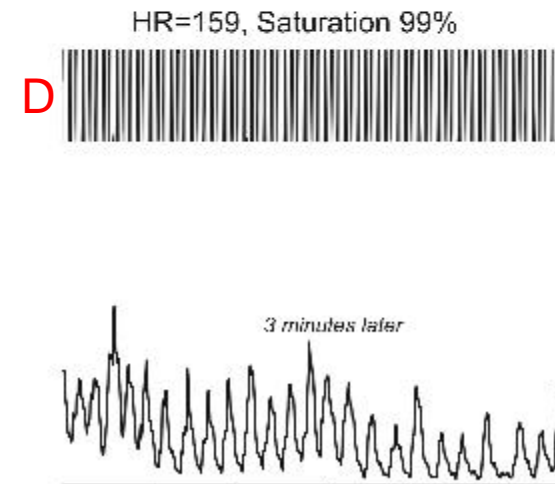
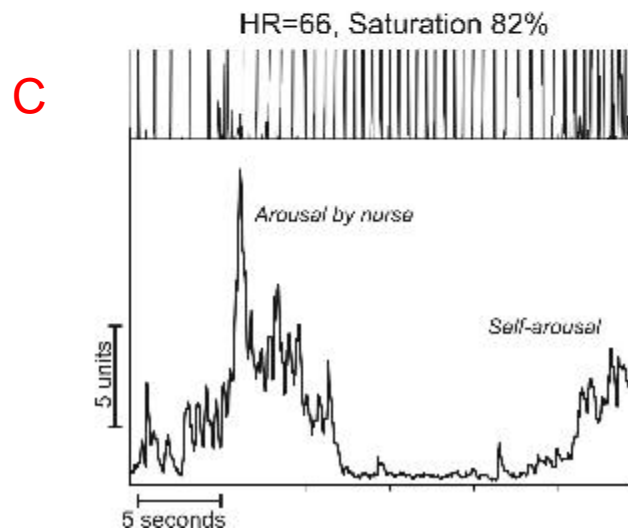
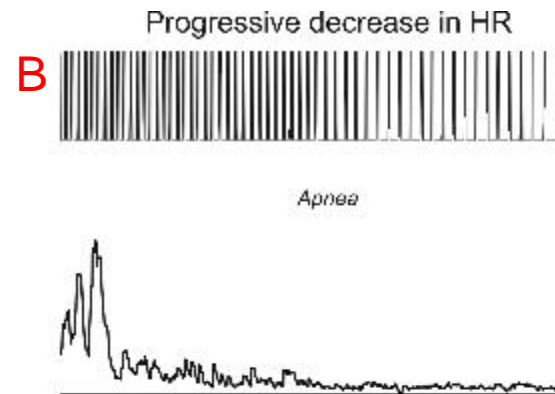
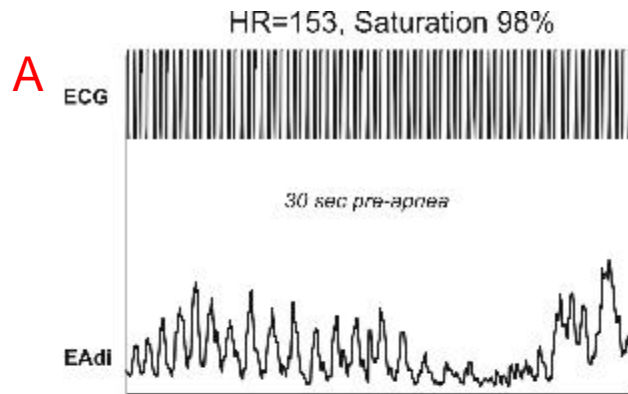
Butler Respir Physiol Neurobiol 2007

Nti defined to peak	Nti defined to 70% of Peak
Beck 2011	Passath 2010
De Oliva 2012	Moerer 2008
Delisle 2011	Allo 2006
Camarotta 2011	Lecomte 2009
Piquillod 2010	
Spahija 2010	
Parthasarathy 2000	
Colombo 2008	
Emeriaud 2006	

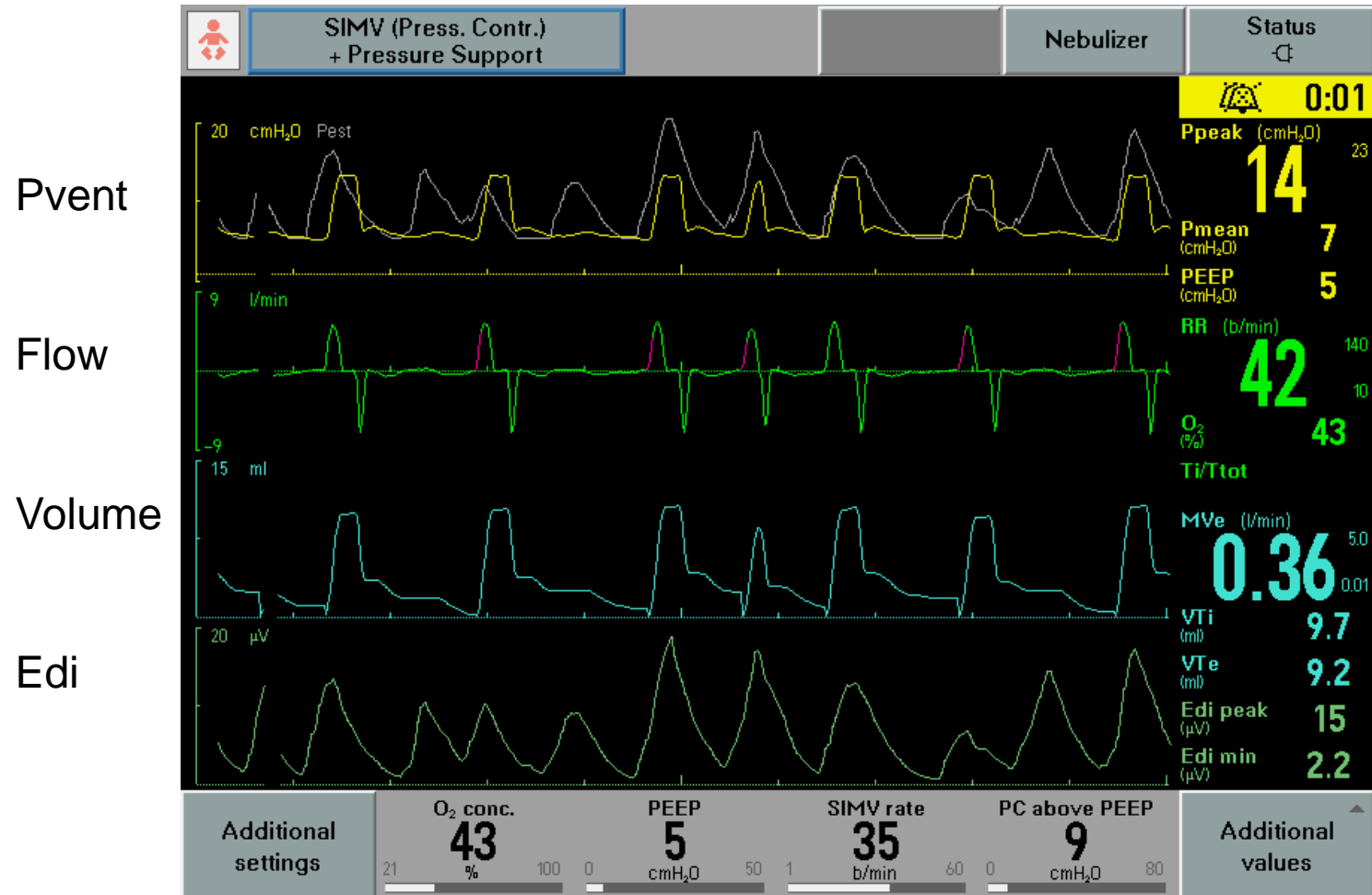
No Edi: Apnea with Sedation



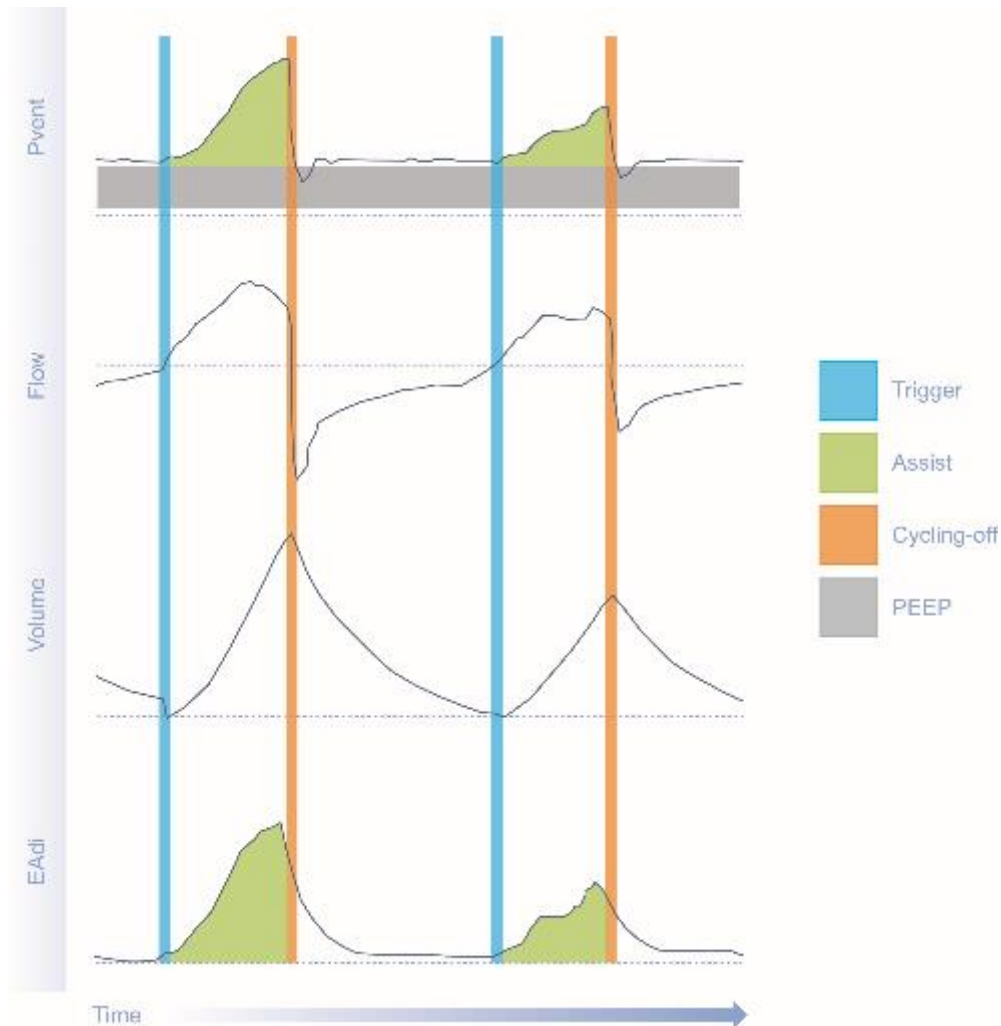
No Edi: Detecting Central Apnea



Edi and Patient-ventilator Interaction



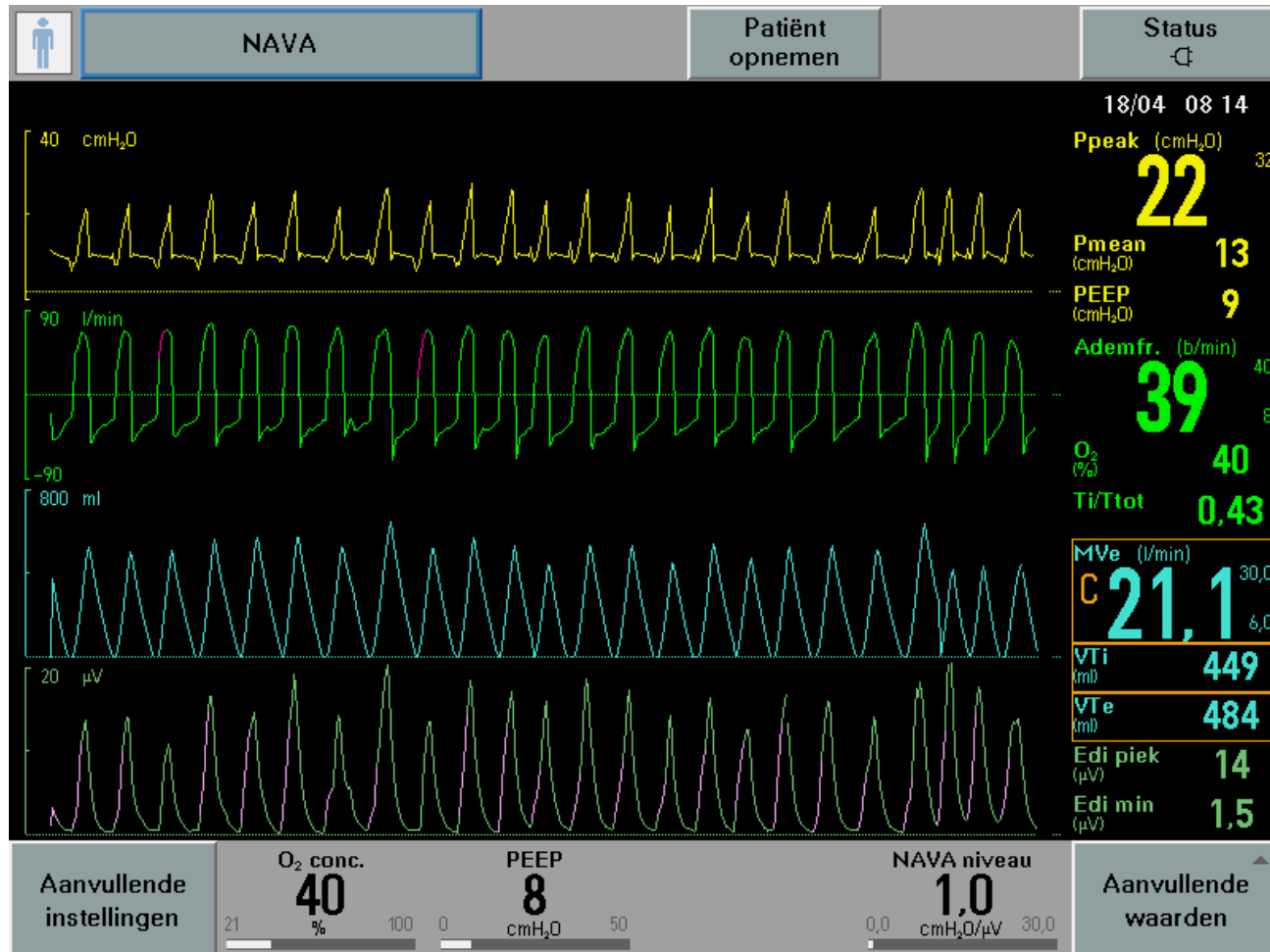
Edi and Controlling Mechanical Ventilation: NAVA



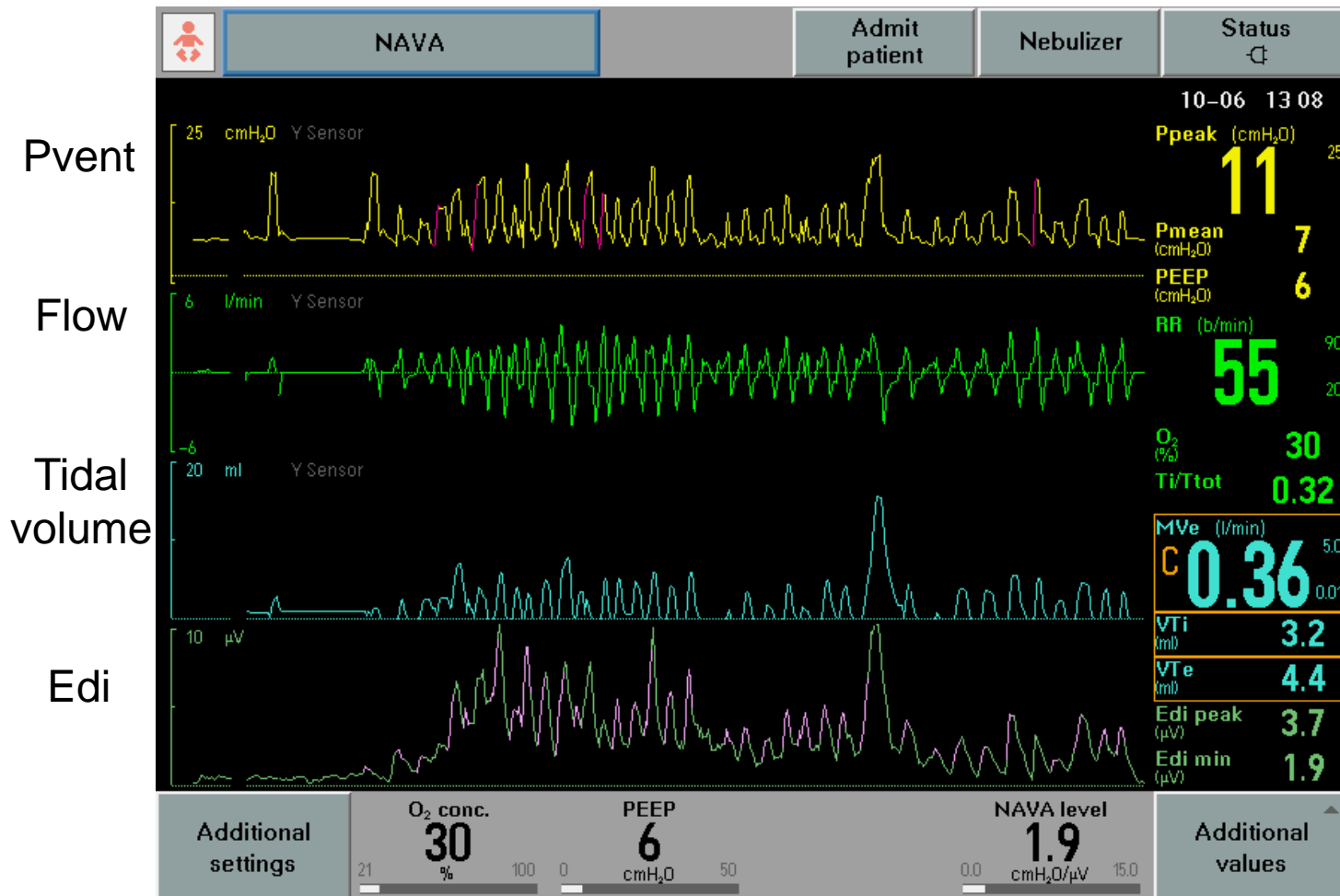
Safety

- i Upper pressure limits
- i Backup ventilation
- i Hiccups

NAVA in the Adult



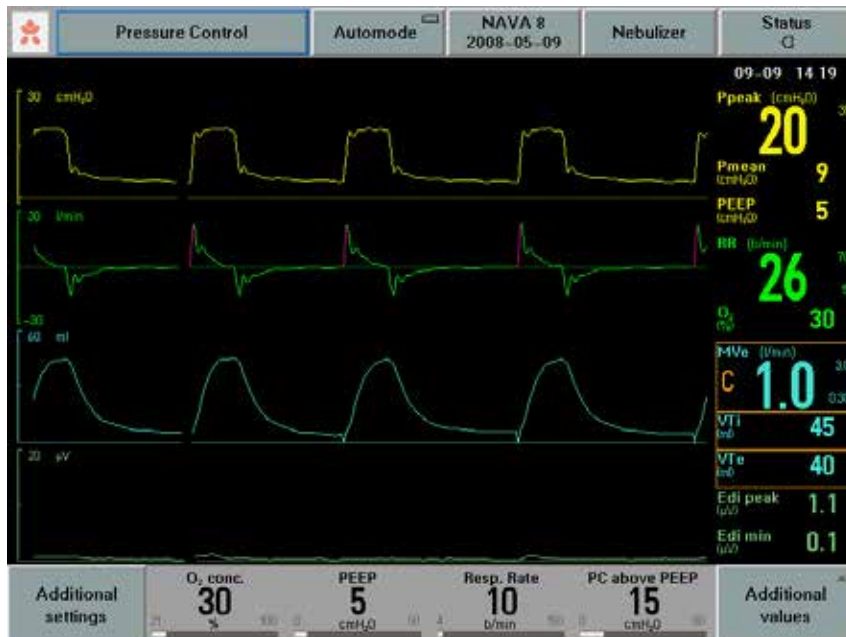
NAVA in the preterm



with permission, E Bancalari Jackson Memorial University of Miami

NAVA Encourages Spontaneous Breathing

PCV

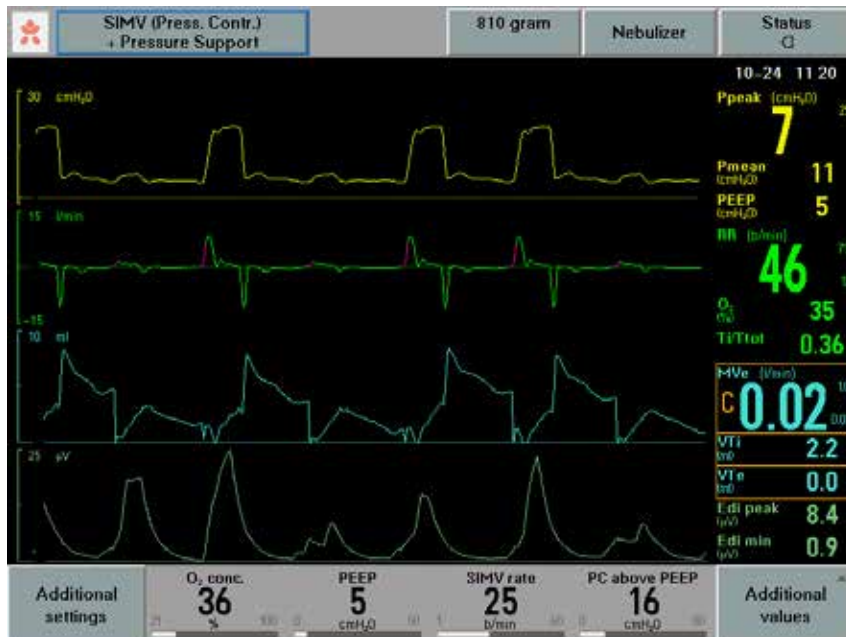


NAVA



NAVA improves synchrony (810 g)

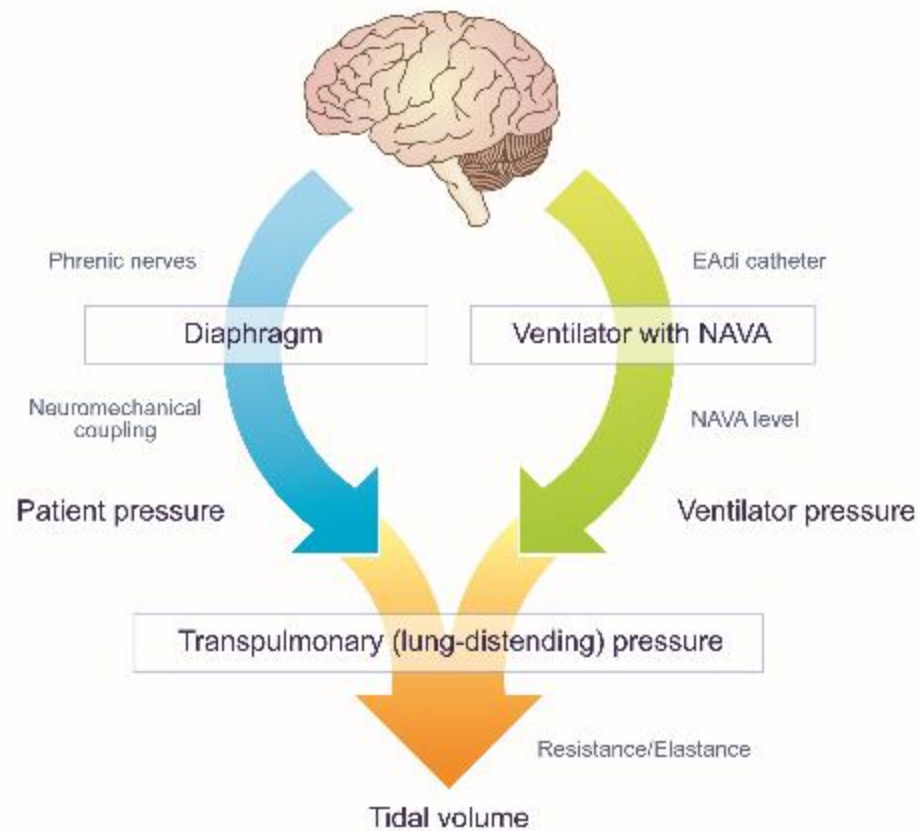
SIMV



NAVA



NAVA is an Artificial Respiratory Muscle



Setting the NAVA Level

- Match pressure to PSV or PC ("Preview window") (n=8)
- Titration (n=3)
- Target Edi (e.g. target 60% of Edi observed during spontaneous breathing trial) (n=1)
- Match minute ventilation observed in PSV (n=1)
- Target Vt (n=1)
- Protocols!

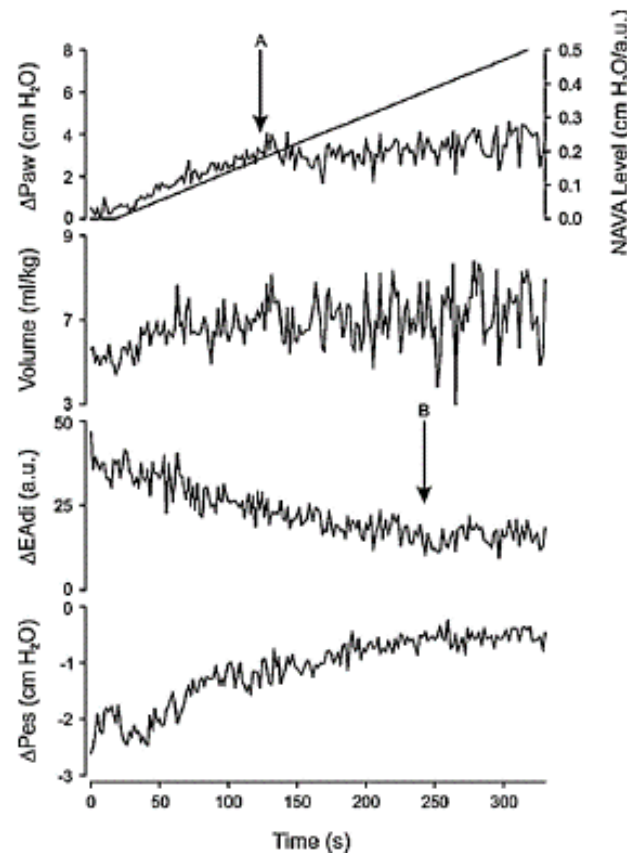
Use of overlay window to adjust NAVA level



Titration Method

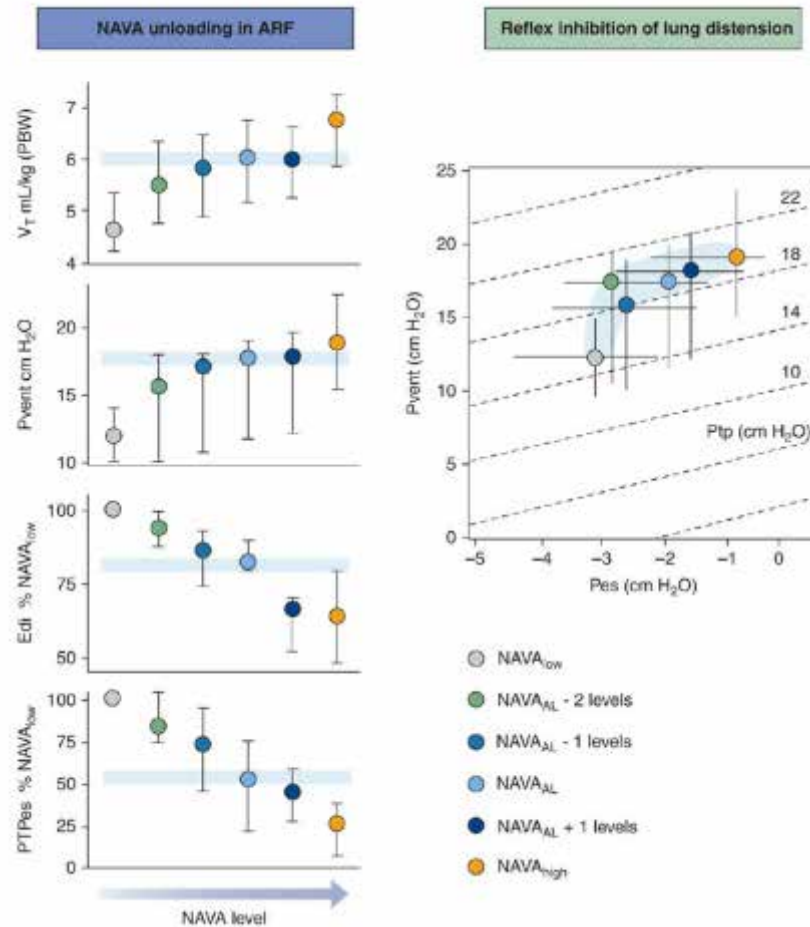
Physiological response to increasing levels of neurally adjusted ventilatory assist (NAVA)

François Lecomte^{a,1}, Lukas Brander^b, Fredrick Jalde^c, Jennifer Beck^d, Haibo Qui^e, Caroline Elie^f, Arthur S. Slutsky^{d,g}, Fabrice Brunet^{d,g}, Christer Sinderby^{d,g,*}



Titration Method

PRINCIPLES AND PRACTICE OF MECHANICAL VENTILATION, THIRD EDITION



Sinderby & Beck, Neurally Adjusted Ventilatory Assist in
Principles and Practice of Mechanical Ventilation, Third Edition
Editor: Tobin MJ, McGraw-Hill Medical 2013
Adapted from Brander et al Chest 2009

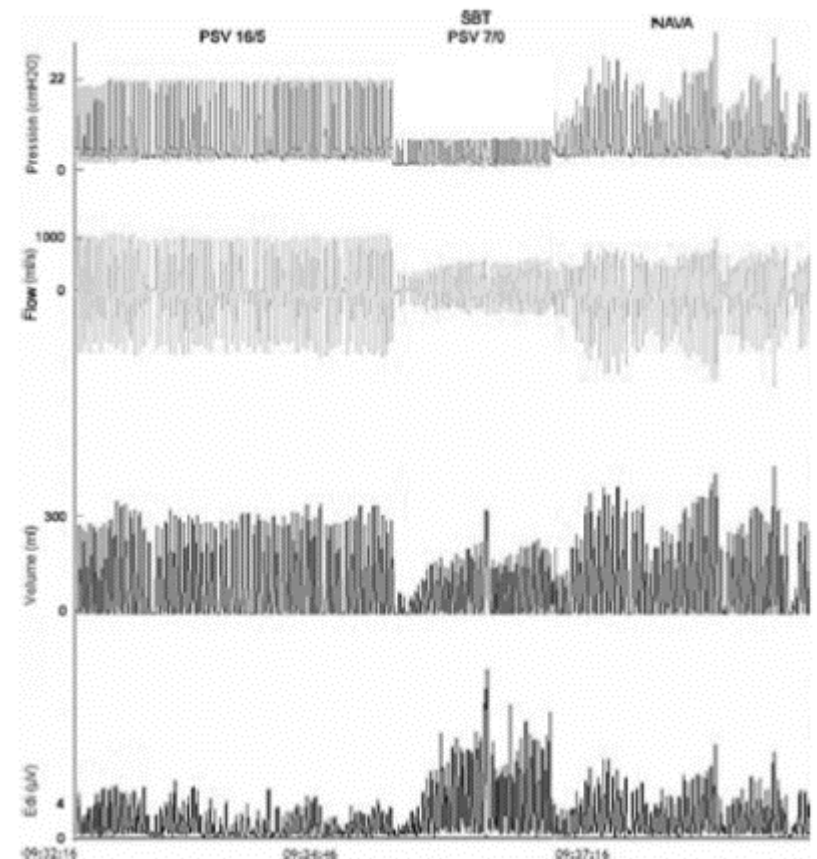
Target Edi

Intensive Care Med
DOI 10.1007/s00134-011-2209-1

ORIGINAL

Hadrien Rozé
Abdelghani Lafrikh
Virginie Perrier
Arnaud Germain
Antoine Dewitte
Francis Gomez
Gérard Janvier
Alexandre Ouattara

**Daily titration
assist using**



Conclusion

What are we doing?

- Providing synchronized and proportional assist
- Ventilator becomes a second respiratory muscle

What do we see?

- The Edi is a physiological signal representative of central respiratory output
- Edi is normally present in spontaneously breathing subject and the waveform has a characteristic cyclic/ phasic pattern with quantifiable measurements of amplitude and timing
- The Edi is essentially a vital sign, just like the electrocardiogram
- The Edi allows answers to the following questions:
 - Is my patient breathing?
 - Does my patient respond to intervention?
 - Is my patient synchronous with the ventilator?