Update on NAVA studies

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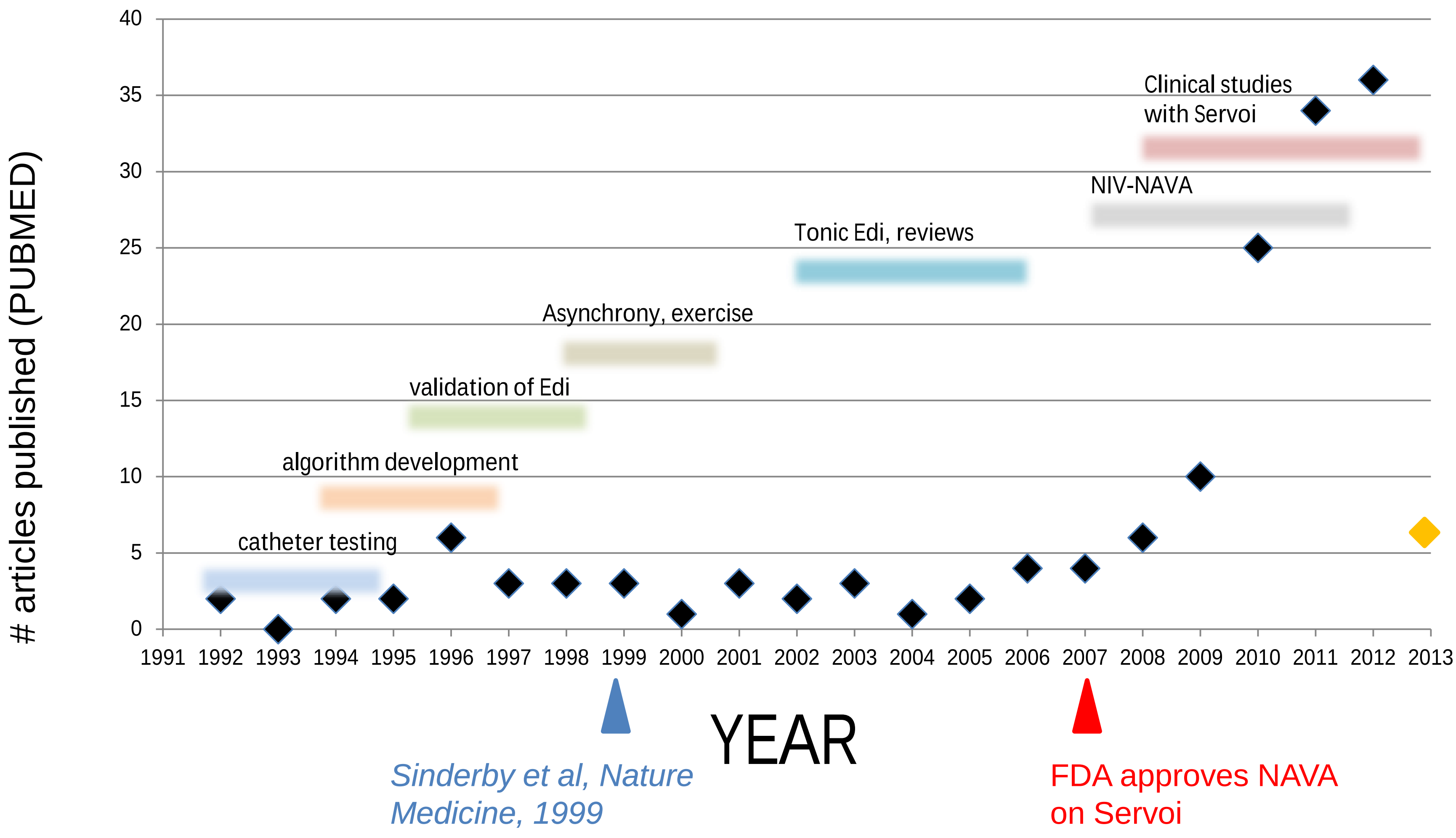
Disclosure

- 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.

The Evolution of Edi and NAVA



Revised April 29, 2013

Neural control of mechanical ventilation in respiratory failure

Christer Sinderby[1,2], Paolo Navalesi[3], Jennifer Beck[4], Yoanna Skrobik[1], Norman Comtois[1], Sven Friberg[5], Stewart B. Gottfried[6] & Lars Lindström[5]

NATURE MEDICINE • VOLUME 5 • NUMBER 12 • DECEMBER 1999

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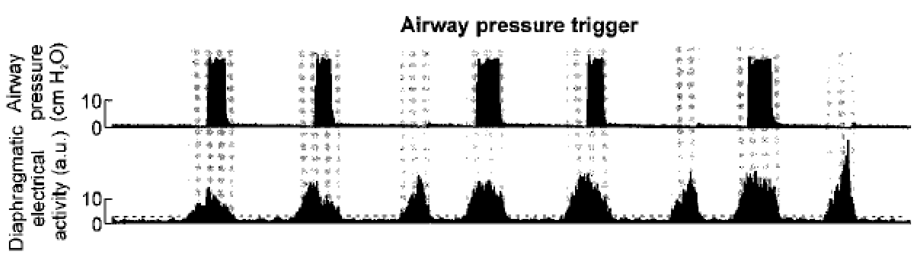

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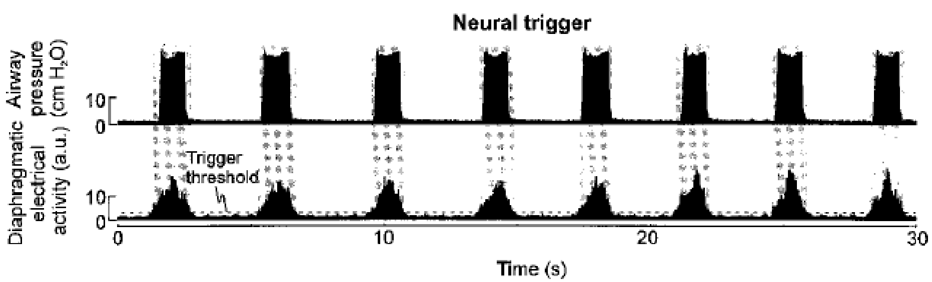
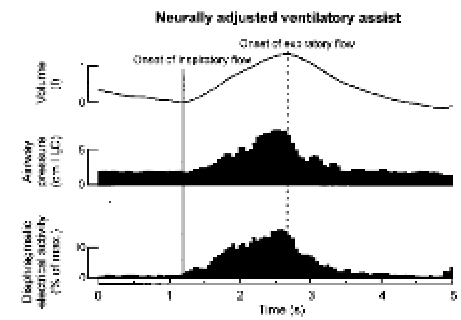


a



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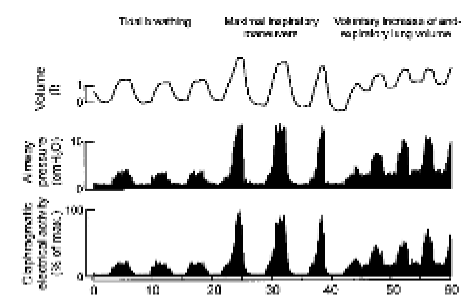
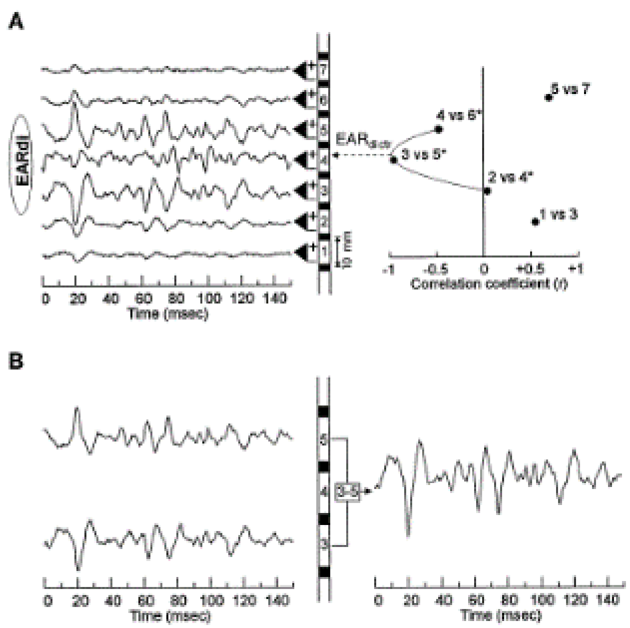


Edi Catheter and Signal Processing

special communication

Enhancement of signal quality in esophageal recordings of diaphragm EMG

CHRISTER A. SINDERBY,[1,2,3] JENNIFER C. BECK,[1,2]
LARS H. LINDSTRÖM,[4] AND ALEJANDRO E. GRASSINO[1,2]
[1]*Meakins Christie Laboratories, McGill University, Montreal H2X 2P2;* [2]*Notre Dame Hospital, University of Montreal, Montreal, Quebec, Canada H2L 4M1; and* [3]*Spinal Injuries Unit and* [4]*Department of Medical Information Processing, Sahlgrenska Hospital, University of Göteborg, S-41345 Göteborg, Sweden*



J. Appl. Physiol. 82(4): 1370–1377, 1997.

American Thoracic Society/European Respiratory Society

ATS/ERS Statement on Respiratory Muscle Testing

This Joint Statement of the American Thoracic Society (ATS), and the European Respiratory Society (ERS) was adopted by the ATS Board of Directors, March 2001 and by the ERS Executive Committee, June 2001

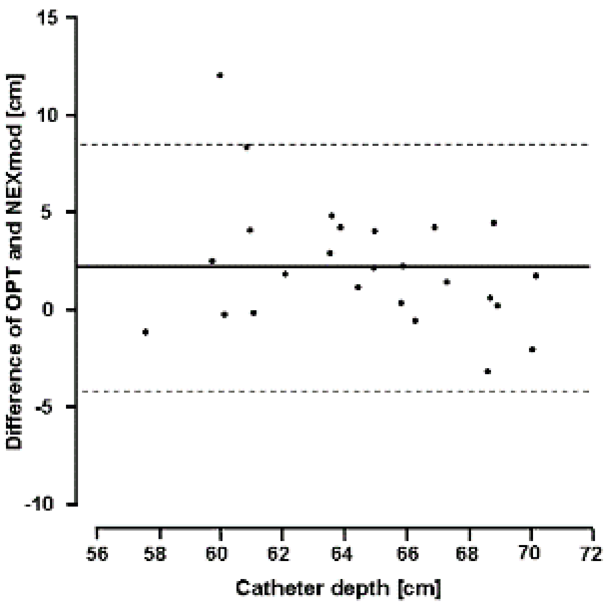
Am J Respir Crit Care Med Vol 166. pp 518–624, 2002
DOI: 10.1164/rccm.166.4.518
Internet address: www.atsjournals.org

Intensive Care Med
DOI 10.1007/s00134-009-1587-0

PHYSIOLOGICAL AND TECHNICAL NOTES

Jürgen Barwing
Markus Ambold
Nadine Linden
Michael Quintel
Onnen Moerer

Evaluation of the catheter positioning for neurally adjusted ventilatory assist



N = 26 Adult ICU
Predicted position vs. *verified position* (positioning window)
N= 18 predicted OK for NAVA
N = 4 predicted = verified
Differences ranged from -2 cm (too far out) to -12 cm (too far in)

nerves. *Conclusions:* EAdi-catheter placement based on the NEX_{mod} formula allows running NAVA in about two-thirds of all patients. The additional tools provided are efficient and facilitate the correct positioning of the EAdi-catheter for neurally adjusted ventilatory assist.

Intensive Care Med
DOI 10.1007/s00134-011-2373-3

PHYSIOLOGICAL AND TECHNICAL NOTES

Jürgen Barwing
Cristina Pedroni
Michael Quintel
Onnen Moerer

Influence of body position, PEEP and intra-abdominal pressure on the catheter positioning for neurally adjusted ventilatory assist

N = 21 Adult ICU
Changed posture, PEEP and Abdominal Pressure
Monitored the optimal position

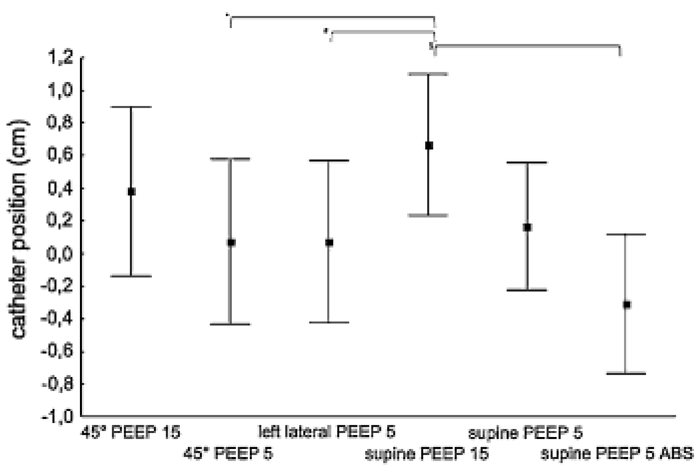


Fig. 1 Optimal catheter positions determined by "highlighted central leads" displayed as mean (*filled squares*) with 95% confidence interval (*whiskers*) for six different situations; *y-axis* catheter position in cm from OPT. Significant differences in post hoc paired comparison (Tukey–Kramer) for 45° PEEP 5 vs supine PEEP 15 ($^{*}p = 0.002$), left lateral PEEP 5 vs supine PEEP 15 ($^{\#}p = 0.006$) and supine PEEP 15 vs supine PEEP 5 ASB ($^{\S}p = 0.0005$) ($n = 21$)

Conclusion

PEEP, BP and IAP affect the optimal EAdi catheter position. NAVA ventilation is not affected due to the wide electrode array compensating for the small diaphragmatic shift seen with such changes. However this only holds true if an optimal catheter position is ensured in advance.

Neurally adjusted ventilatory assist: assessing the comfort and feasibility of use in neonates and children

Anita Duyndam, Bas SP Bol, André Kroon, Dick Tibboel and Erwin Ista

Table 1 Questionnaire requesting information relating to the NAVA catheter

1. Is it clear that the nasal gastric tube is suitable for NAVA?	Yes/no	All yes
2. Is there a clear metric scale on the NAVA catheter?	Yes/no	All yes
3. How does the material feel?	Rigid/weak/same as standard nasogastric tubes	1 weak
4. How do you experience the flexibility of the NAVA catheter?	Rigid/same as standard nasogastric tubes/flexible	1 weak
5. Is the catheter easy to manipulate according the guidelines of Maquet?	Yes/no	All yes
6. Is the catheter easy to fixate with common adhesive plaster?	Yes/no	All yes
7. Does the catheter remain in place after fixation?	Yes/no	All yes
8. Is the NEX method appropriate for this child to get the Edi signal well on the screen?	Yes/no, too short/long (. . . . . . . cm)	*
9. What is your overall impression of the use of the Edi catheter?	Weak/ adequate /good Comments:	All good

NAVA, neurally adjusted ventilatory assist; NEX, nose, ear, xiphisternum.

N = 21 (19 NICU, 11 PICU)
Insert catheter and recorded 3h CV – 3 h NAVA (match Pk P) – 3 h CV
Questionnaire
Safety criteria clearly defined

Edi Values and Use of Edi Monitoring

Published Edi$_{pk}$ (on Servoi)

Catheter size	Condition	Mean Edipk (uV)	Lowest mean value Edi pk (uV)	Highest mean value Edi pk (uv)	# studies	# patients
16	Intubated on NAVA	10.4	4	15	16	204
16	NIV-NAVA	19.2	11	33	4	53
8	Intubated on NAVA	10.6	10	11	3	25
8	*NIV-NAVA*	*20*			*1*	*9*
6	Intubated on NAVA	9.4	7.4	11.4	3	47
6	NIV-NAVA				0	0
6	No assist	11	10	16	1	3 (healthy)
ALL		13.1	4	33	32	482

Revised April 26, 2013

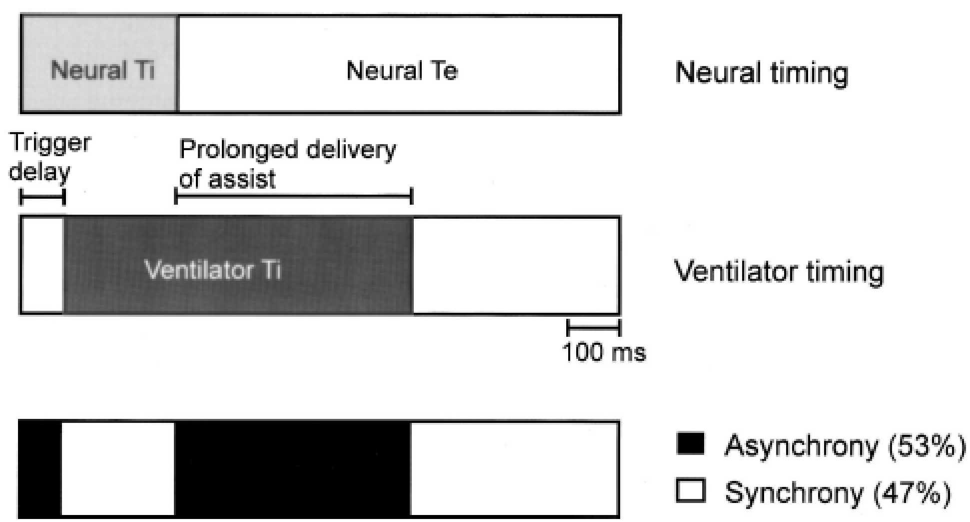
0031-3998/04/5505-0747
PEDIATRIC RESEARCH

Vol. 55, No. 5, 2004
Printed in U.S.A.

Prolonged Neural Expiratory Time Induced by Mechanical Ventilation in Infants

JENNIFER BECK, MARISA TUCCI, GUILLAUME EMERIAUD, JACQUES LACROIX, AND CHRISTER SINDERBY

Pediatric Intensive Care Unit, Department of Pediatrics and Hôpital Sainte-Justine Research Center, Université de Montréal, Montreal, Quebec H3T 1C5 [J.B., M.T., G.E., J.L.]; Department of Newborn and Developmental Pediatrics, Sunnybrook and Women's College Health Sciences Centre, Toronto, Ontario M5S 1B2 [J.B.]; and Department of Critical Care Medicine, St-Michael's Hospital, Toronto, Ontario M5B 1W8 [C.S.], Canada



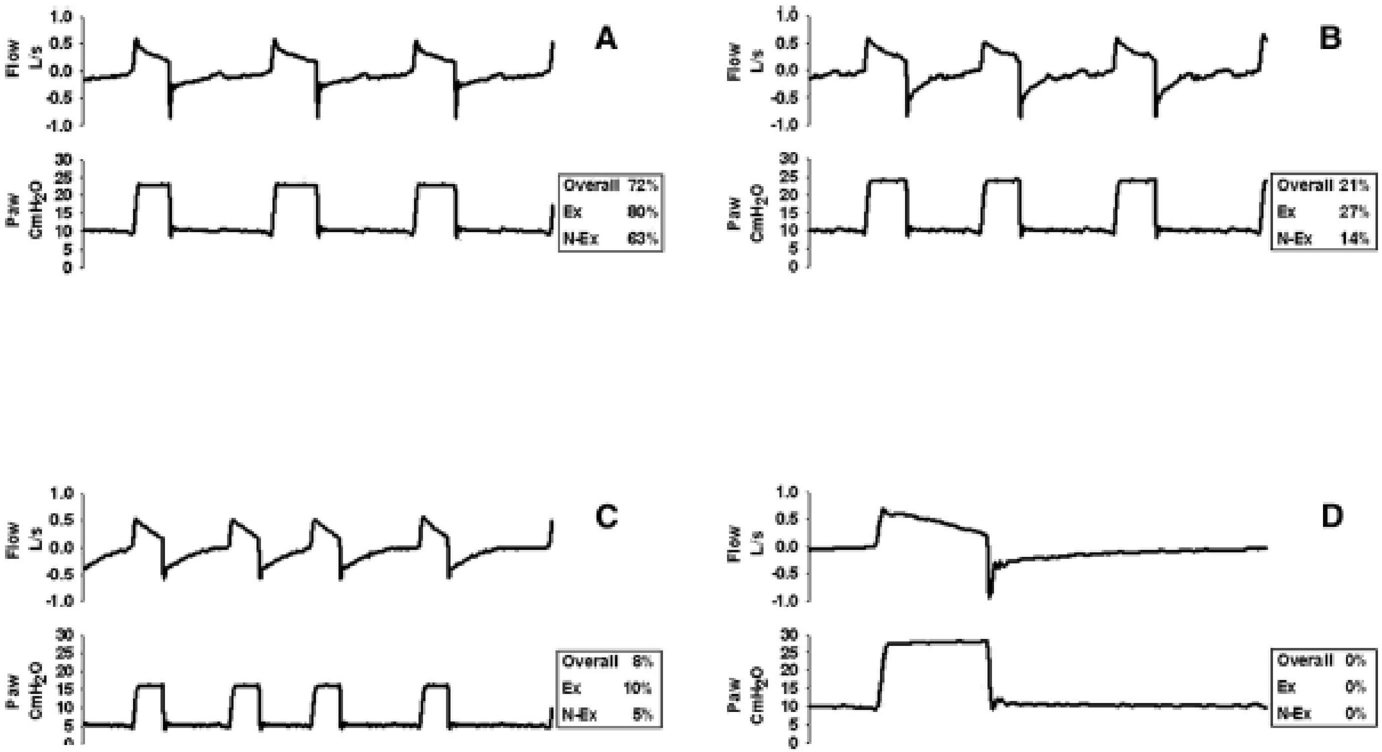
N = 14
Mean weight = 3.9 kg
Mean age = 2.3 mos

Figure 4. Patient–ventilator interaction during mandatory breaths. Schematic representation of patient neural timing (*upper bar*) and ventilator timing (*middle bar*) during mandatory breaths. *Upper bar,* neural Ti (*gray area*) and neural Te (*white*) for the group data are presented. *Middle bar,* periods describing ventilator timing are displayed, including trigger delay and ventilator Ti. *Bottom bar,* periods of infant–ventilator synchrony (*white*) and asynchrony (*black*).

Efficacy of ventilator waveforms observation in detecting patient–ventilator asynchrony*

Davide Colombo, MD, PhD; Gianmaria Cammarota, MD; Moreno Alemani, MD; Luca Carenzo, MD;
Federico Lorenzo Barra, MD; Rosanna Vaschetto, MD, PhD; Arthur S. Slutsky, MD;
Francesco Della Corte, MD; Paolo Navalesi, MD

Crit Care Med 2011 Vol. 39, No. 11



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J Coll Physicians Surg Pak. 2013 Feb;23(2):154-6. doi: 02.2013/JCPSP.154156.

Neurally adjusted ventilatory assist (NAVA) mode as an adjunct diagnostic tool in congenital central hypoventilation syndrome.

Rahmani A, Ur Rehman N, Chedid F.

Department of Paediatrics, Tawam Hospital in association with Johns Hopkins Medicine, Al Ain, United Arab Emirates.

Abstract

A full term female newborn was admitted to the neonatal intensive care unit (NICU) for continuous observation of apnea. Infant was noted to have apnea while asleep requiring intubation and mechanical ventilation. A video EEG was performed which demonstrated normal awake background without any seizure activity. Neurally adjusted ventilatory assist (NAVA) demonstrated the absence of electrical activity of the diaphragm (Edi) when the patient was in quiet phase of sleep. This finding on NAVA monitor raised the suspicion of central hypoventilation syndrome (CCHS) which was confirmed by genetic identification of the PHOX2B mutation.

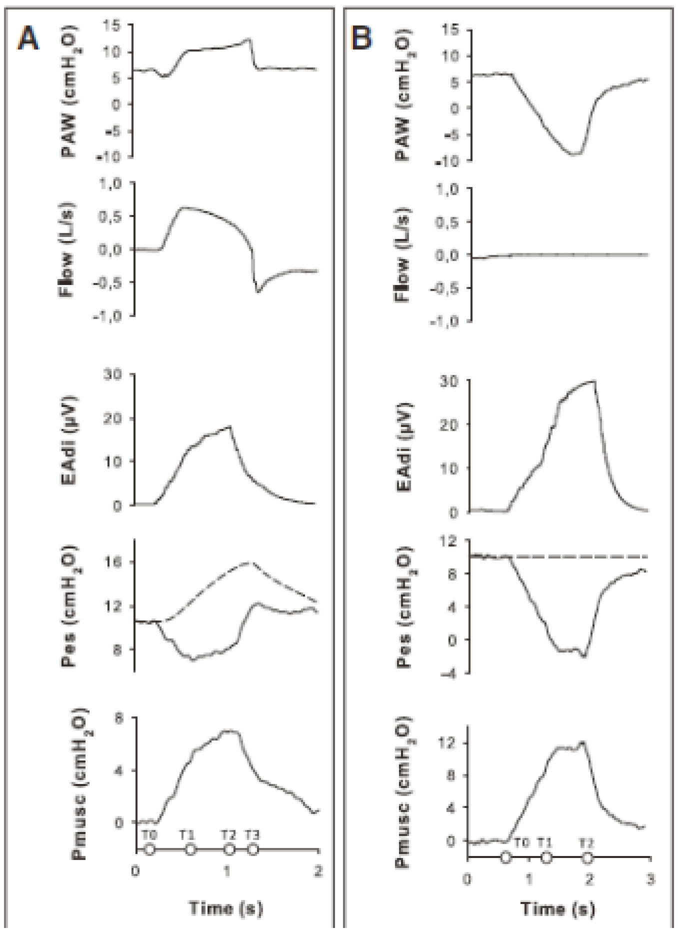
PMID: 23374524 [PubMed - in process]

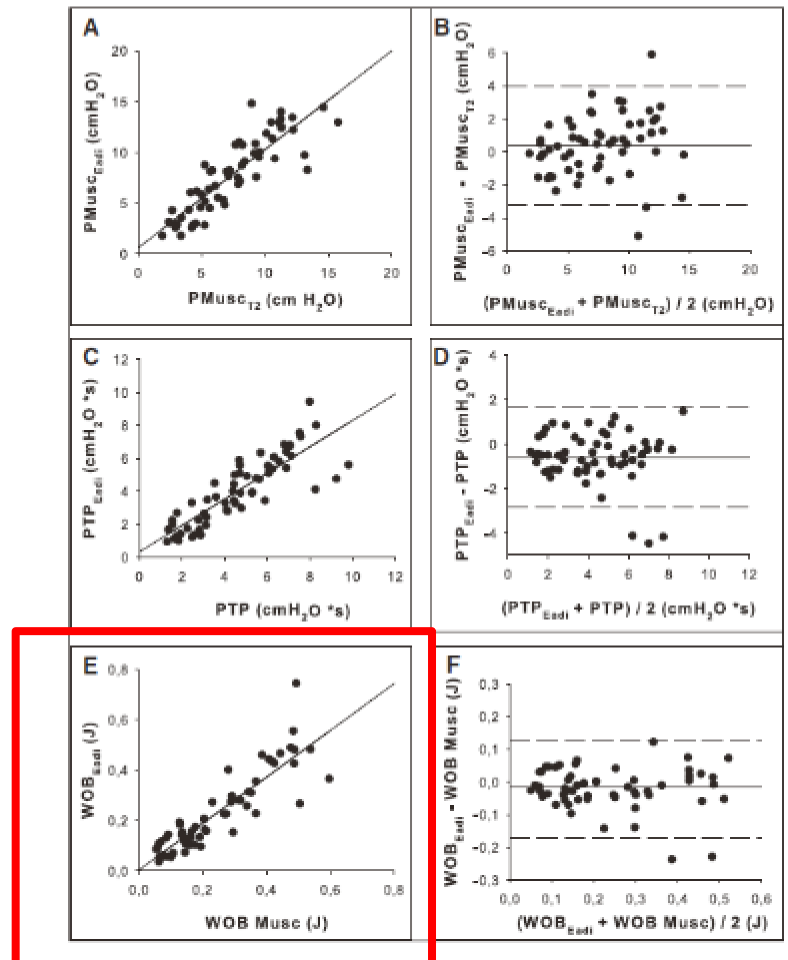
LinkOut - more resources

Estimation of Patient's Inspiratory Effort From the Electrical Activity of the Diaphragm

Giacomo Bellani, MD, PhD[1,2]; Tommaso Mauri, MD[1,2]; Andrea Coppadoro, MD[1,2];
Giacomo Grasselli, MD[2]; Nicolò Patroniti, MD[1,2]; Savino Spadaro, MD[2]; Vittoria Sala, MD[1,2];
Giuseppe Foti, MD[2]; Antonio Pesenti, MD[1,2]

CCM, March 8, 2013





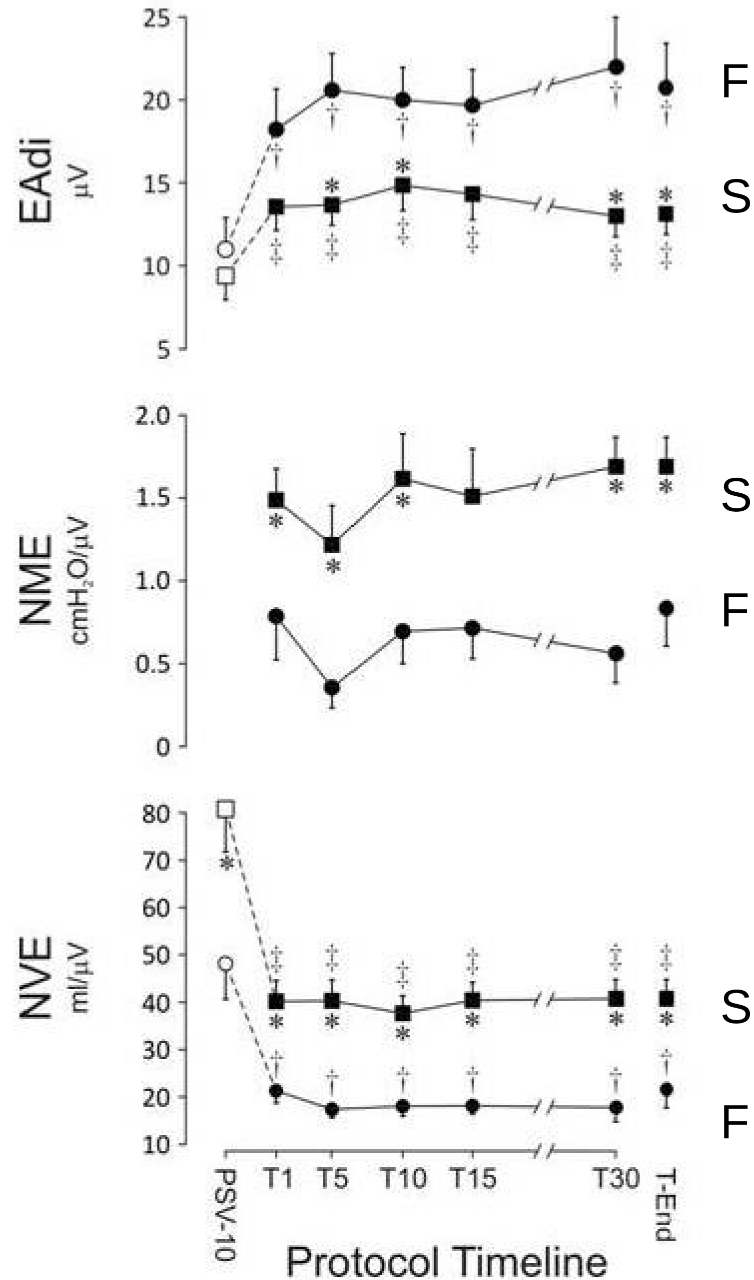
Liu et al. Critical Care 2012, 16:R143
http://ccforum.com/content/16/4/R143

CRITICAL CARE

RESEARCH Open Access

Neuroventilatory efficiency and extubation readiness in critically ill patients

Ling Liu[1], Huogen Liu[1], Yi Yang[1], Yingzi Huang[1], Songqiao Liu[1], Jennifer Beck[2,3], Arthur S Slutsky[2,4], Christer Sinderby[2,4*] and Haibo Qiu[1]



N = 52 Adult ICU
Edi, NME, NVE
30 min SBT (CPAP = 5)
Success (35) vs. Failure (17)

Dres et al. ICM 2012
N = 57 Adult ICU
Edi, NME, NVE
30 min SBT (PSV 7, PEEP 0)
Success (35) vs. Failure (22)

NAVA and Synchrony

Intensive Care Med (2011) 37:1826–1832
DOI 10.1007/s00134-011-2352-8

PEDIATRIC ORIGINAL

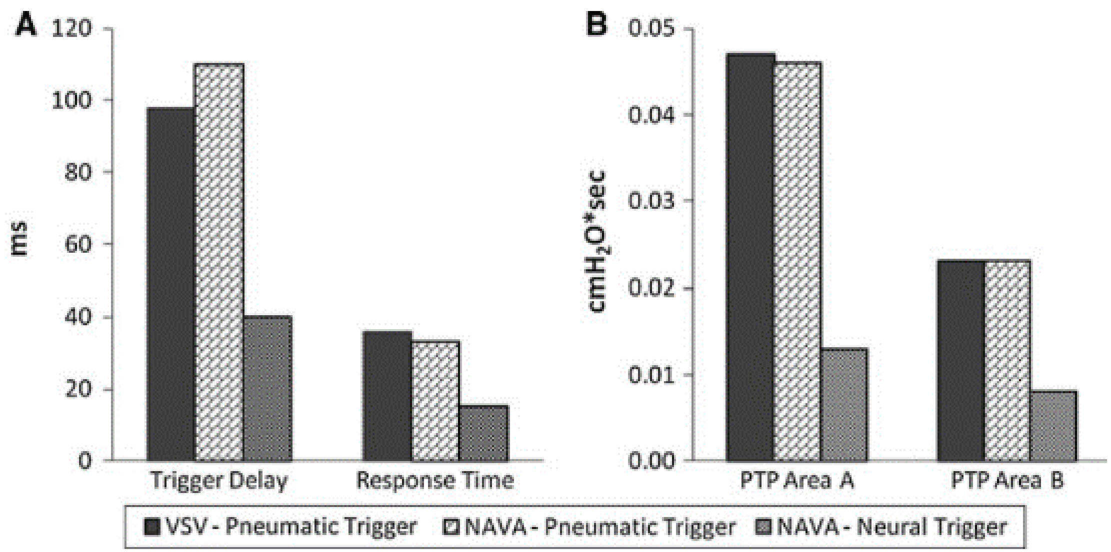
Katherine C. Clement
Tracy L. Thurman
Shirley J. Holt
Mark J. Heulitt

Neurally triggered breaths reduce trigger delay and improve ventilator response times in ventilated infants with bronchiolitis

Table 1 Demographic data

	n (%)
Sex	
Males	12 (52.2)
Females	11 (47.8)
Race	
White, non-Hispanic	12 (52.2)
Hispanic	5 (21.7)
African American	4 (17.3)
Other	2 (0.09)
Primary diagnosis	
RSV bronchiolitis	14 (60.8)
Apnea	5 (21.7)
Bronchiolitis	4 (17.3)
	Mean ± SD
Age (months)	1.6 ± 1.0
Weight (kg)	4.2 ± 1.4
Pulse Ox saturation (%)	97 ± 2
Heart rate (bpm)	142 ± 15
Temperature (°C)	36.5 ± 0.6
Blood pressure—systolic (mmHg)	90 ± 15
Blood pressure—diastolic (mmHg)	53 ± 11
Total days in hospital	21 ± 11
Total days in PICU	12 ± 6
Total days on ventilator	9 ± 5
Sedation scale	
Pre-NAVA mode	20 ± 3
Pre-VS mode	20 ± 3

Total $n = 23$



Comparison of Pressure-, Flow-, and NAVA-Triggering in Pediatric and Neonatal Ventilatory Care

Merja Ålander, MD,[1]* Outi Peltoniemi, MD, PhD,[1] Tytti Pokka, BSc,[1] and Tero Kontiokari, MD, PhD[2]

Pediatric Pulmonology 08/2011

TABLE 1—Patient Characteristics

N	Gender	Age	Diagnosis
1	F	10.8 years	Post op. analgesia, mental retardation
2	M	2 months	Cystic lung malformation, post op.
3	F	1 month	RSV-bronchiolitis
4	M	2.6 years	Esophagitis, post op.
5	M	13.8 years	Scoliosis, post op.
6	M	10 months	Pneumonia l.a.
7	F	3.8 years	Pneumonia Cockayne sdr,
8	F	9 hr	RDS Prematurity (h33 + 0),
9	F	13.2 years	Scoliosis, post op. Spastic tetraplegy
10	M	4 months	RSV-bronchiolitis
11	F	1 month	Facial nevus, post op.
12	F	3 weeks	Aortic anomaly, post op.
13	M	4 hr	Prematurity (h34 + 5)
14	M	9 hr	RDS Prematurity (h35 + 2),
15	M	9 hr	RDS Prematurity (h30 + 1),
16	M	3 months	Cranioplasty, post op. Sdr Apert
17	F	8.3 years	Acute appendicitis and peritonitis
18	M	43 hr	Neonatal sepsis

TABLE 2—The Effect of Trigger Mode in Patient-Ventilator Intera

	Pressure trigger	Flow trigger	NAVA	ANOVA P[1]
Follow-up time (sec)				
Mean	678	622	674	
Range	592–931	545–930	541–978	0.223
Low Edi-signal[2] (sec)				
Mean	58.5	85.1	10	
Range	0–267	0–529	0–66	0.077[3]
Low Edi-signal (%)				
Mean	8.1	12.2	1.3	
Range	0–29	0–57	0–8	0.036[3]
SD	10.2	18.5	2.8	
Asynchrony (%)				
Mean	33.4	30.8	8.8	
Range	10–57	16–48	4–15	<0.001
SD	12.6	8.2	3.3	
Asynchrony (%) (Low Edi interpreted as synchrony)				
Mean	31.4	27.5	8.7	
Range	7–57	8–48	4–15	<0.001
SD	13.6	8.2	3.2	
Edi min (μV)				
Mean	0.03	0.03	0.04	
Range	0–0.20	0–0.22	0–0.22	0.660[3]
Edi max (μV)				
Mean	22.8	22.0	28.8	
Range	2.4–51.9	4.0–53.2	3.1–79.6	0.139

Pressure, Flow, NAVA, 10 min each

Neurally adjusted ventilatory assist improves patient–ventilator interaction in infants as compared with conventional ventilation

Alice Bordessoule[1], Guillaume Emeriaud[1], Sylvain Morneau[1], Philippe Jouvet[1] and Jennifer Beck[2,3]

Pediatric RESEARCH Volume 72 | Number 2 | August 2012

Table 3. Patient–ventilator interaction and respiratory variability

	NAVA	PCV	PSV	*P* value[a]
Patient–ventilator interaction				
Trigger delay (ms)	93 (20)	193 (87)	135 (29)	$P < 0.001$ – PCV vs. NAVA and PSV vs. NAVA
Cycling-off delay (ms)	17 (13)	12 (176)	−77 (81)	NS
Asynchrony index (%)	11 (3)	24 (11)	25 (9)	$P < 0.001$ – PCV vs. NAVA and PSV vs. NAVA
Wasted efforts (%)	0 (0)	4.3 (4.6)	6.5 (7.7)	$P < 0.05$ – PSV vs. NAVA
Percentage of breaths cycled off too early (%)	0.3 (0.4)	12 (13)	21 (19)	$P < 0.01$ – PCV vs. NAVA and PSV vs. NAVA
Correlation between peak Pvent and peak EAdi				
Determination coefficient R2	0.71 (0.22)	0.15 (0.16)	0.12 (0.12)	$P < 0.001$ – PCV vs. NAVA and PSV vs. NAVA
Slope	1.45 (1.5)	0.07 (0.1)	0.06 (0.04)	$P < 0.01$ – PCV vs. NAVA and PSV vs. NAVA
Respiratory variability				
Peak Edi – CV (%)	49 (27)	50 (29)	51 (32)	NS
Tidal volume – CV (%)	31 (26)	15 (12)	20 (15)	$P = 0.17$
Peak Pvent – CV (%)	24 (8)	2 (1)	2 (2)	$P < 0.01$ – PCV vs. NAVA and PSV vs. NAVA

Means (SD) are presented.

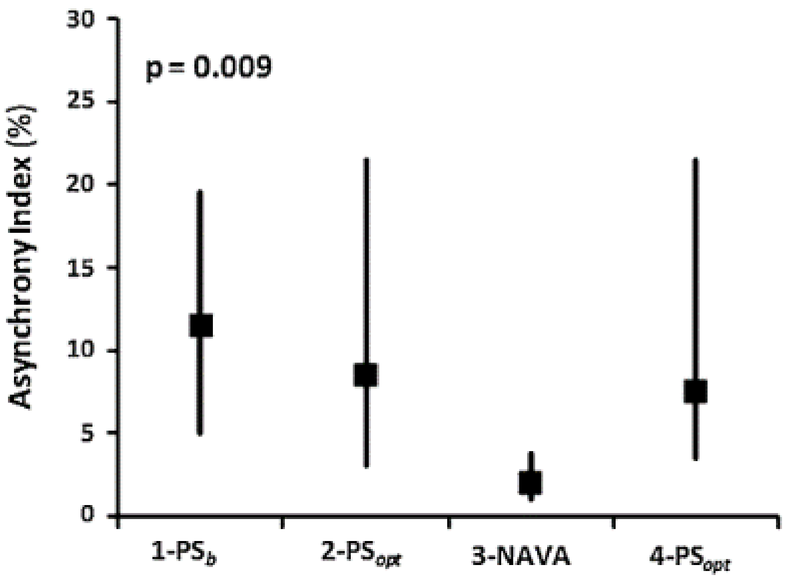
N = 10
Mean weight = 4.3 kg
Mean age = 2 mos
GA at birth: 26 wks

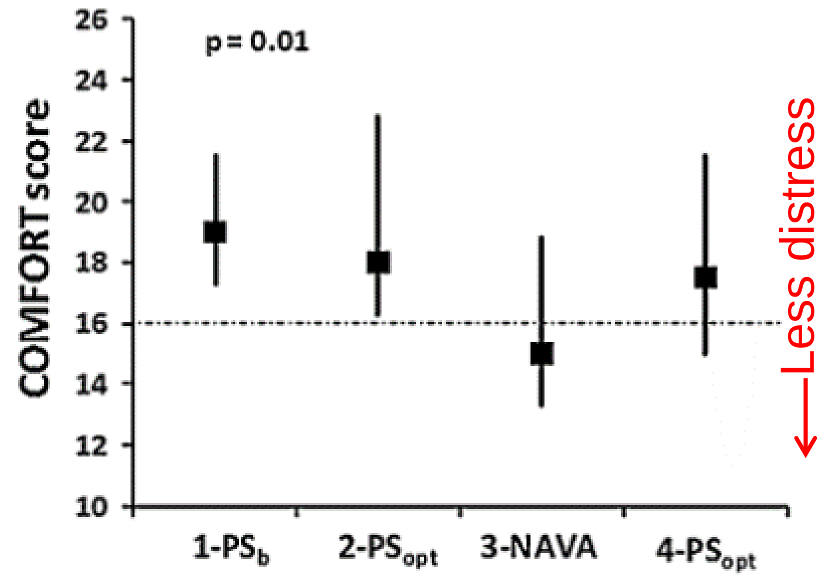
Intensive Care Med
DOI 10.1007/s00134-012-2535-y

PEDIATRIC ORIGINAL

Pedro de la Oliva
Cristina Schüffelmann
Ana Gómez-Zamora
Jesus Villar
Robert M. Kacmarek

Asynchrony, neural drive, ventilatory variability and COMFORT: NAVA versus pressure support in pediatric patients. A non-randomized cross-over trial



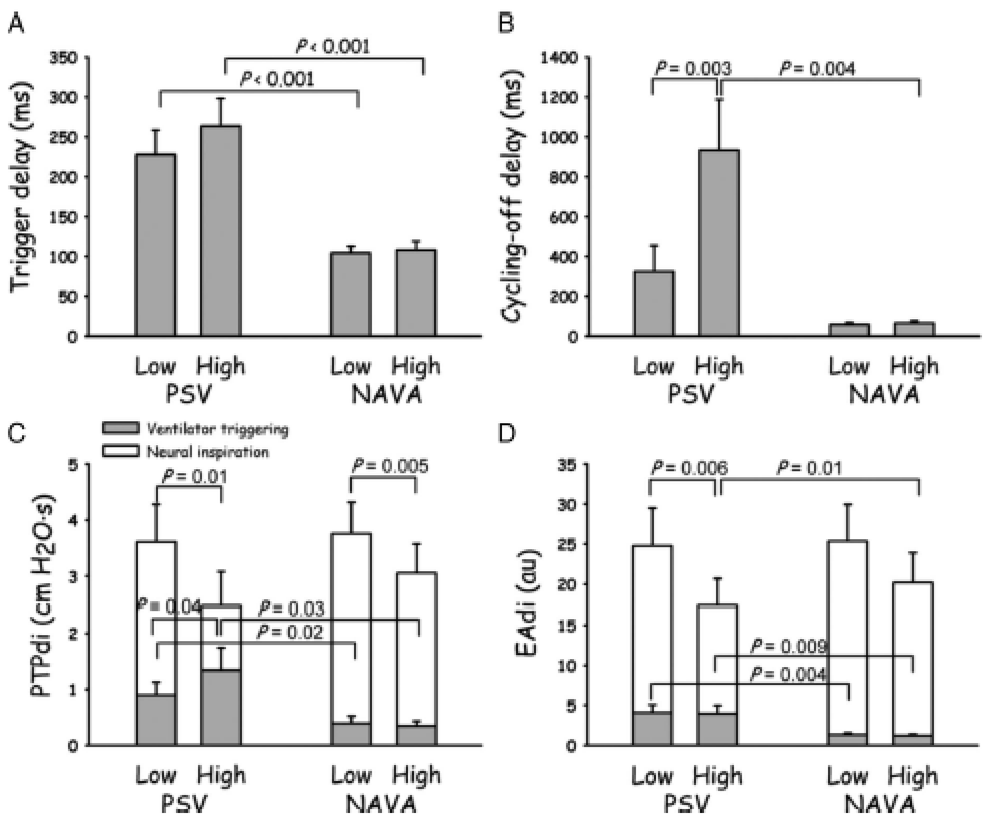


N = 12
Weight = 4.5 – 23kg
Age = 9 days – 7 years
10 min each mode, no sedation adjusted

Patient-ventilator interaction during pressure support ventilation and neurally adjusted ventilatory assist*

Jadranka Spahija, PhD; Michel de Marchie, MD; Martin Albert, MD; Patrick Bellemare, MD;
Stéphane Delisle, MSc; Jennifer Beck, PhD; Christer Sinderby, PhD

Crit Care Med 2010 Vol. 38, No. 2



	Wasted efforts	Aynchrony index
PSVlow	5±4%	18±13%
PSVhigh	31 ± 26%	23 ± 12%
NAVAlow	0	7±2%
NAVA high	0	7±2%

N = 14 Adult ICU (12 COPD)
Low and high PSV (10 min each)
Low and high NAVA (10 min each)
Servo 300

Intensive Care Med
DOI 10.1007/s00134-010-2052-9

ORIGINAL

Lise Piquilloud
Laurence Vignaux
Emilie Bialais
Jean Roeseler
Thierry Sottiaux
Pierre-François Laterre
Philippe Jolliet
Didier Tassaux

Neurally adjusted ventilatory assist improves patient–ventilator interaction

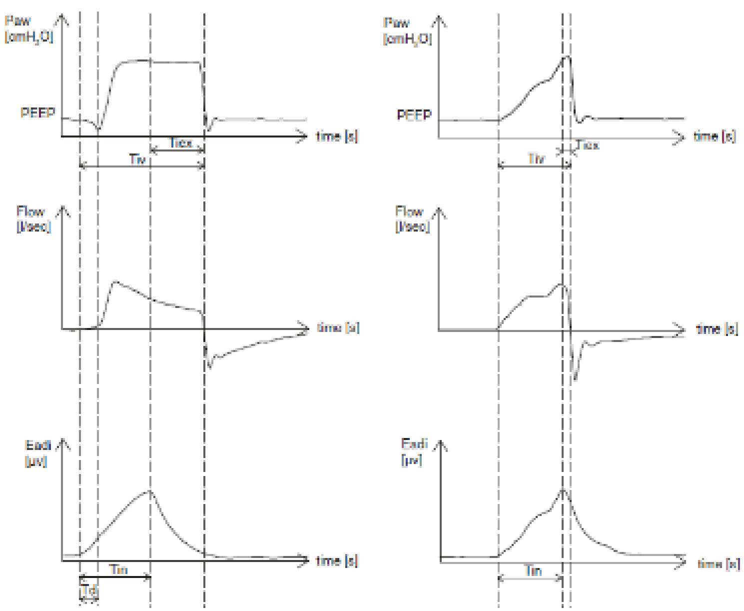


Table 2 Number of total and specific asynchronies per minute as well as other respiratory parameters

	Study period						Repeated-measures ANOVA p
	PS1		NAVA		PS2		
	Median	Centile 25–75	Median	Centile 25–75	Median	Centile 25–75	
Td (ms)	178	139–245	69	57–85	199	135–256	<0.001
Tiex (ms)	204	117–345	126	111–136	220	127–366	0.016
AI (%)	12.0	4.8–26.4	4.5	2.6–9.9	12.8	6.6–28.7	0.016
Total asynchronies (*n*/min)	3.15	1.18–6.40	1.21	0.54–3.36	3.04	1.22–5.31	0.032
Ineffective efforts (*n*/min)	0.81	0.02–1.92	0.00	0.00–0.00	0.67	0.11–1.70	<0.001
Late cycling (*n*/min)	0.12	0–0.63	0.00	0.00–0.00	0.09	0.0–1.15	<0.001
Double triggering (*n*/min)	0.00	0.00–0.04	0.78	0.46–2.42	0.00	0.00–0.00	<0.001
Premature cycling (*n*/min)	0.14	0.00–0.41	0.00	0.00–0.00	0.00	0.00–0.48	<0.001
Autotriggering (*n*/min)	0.14	0.00–0.65	0.09	0.00–0.74	0.09	0.00–0.69	0.555
MV (l/min)	8.8	7.0–11.9	9.2	7.9–12.4	8.8	8.0–12.2	0.293
VTi (ml/kg)	7.3	6.3–7.9	6.6	6.1–7.3	7.5	6.9–8.4	<0.001
RR (*n* cycles/min)	18.8	15.6–25.1	22.9	20.6–30.7	19.1	16.4–28.4	0.002
Pawm (cmH_2O)	10.2	9.5–12.4	9.6	8.7–11.7	10.2	9.4–12.7	<0.001

N = 22
20 min each, PSV, NAVA matched pk P, PSV

NAVA Levels

Acta Anaesthesiol Scand 2011; 55: 1261–1271
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ACTA ANAESTHESIOLOGICA SCANDINAVICA
doi: 10.1111/j.1399-6576.2011.02522.x

Neurally adjusted ventilatory assist vs. pressure support ventilation in critically ill patients: an observational study

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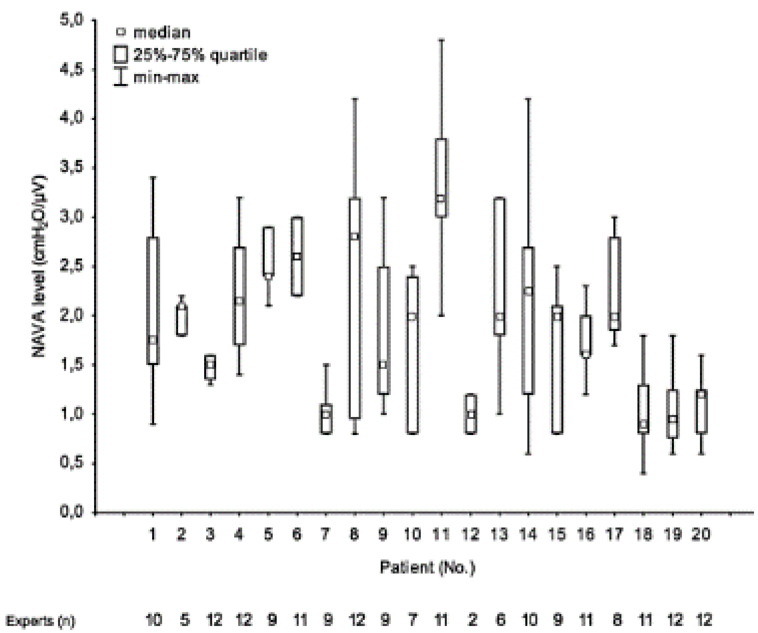
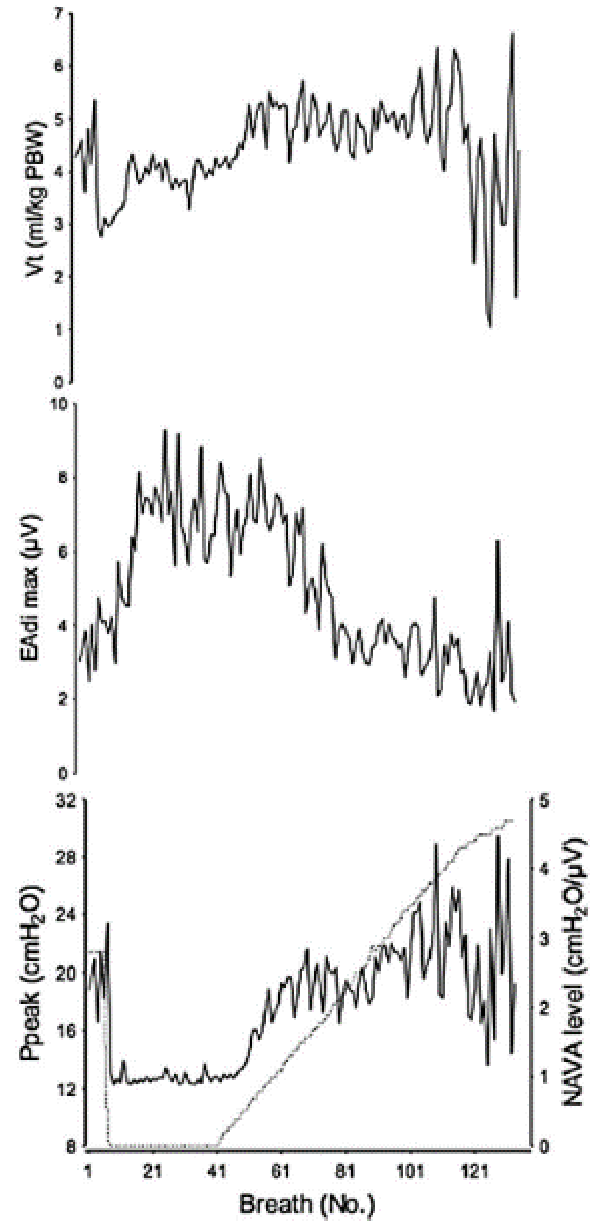
Department of Anesthesiology, Emergency and Intensive Care Medicine, University of Göttingen Medical School, Göttingen, Germany





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

ORIGINAL

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

Daily titration of neurally adjusted ventilatory assist using the diaphragm electrical activity

Table 3 Comparison of respiratory parameters during the first 3 days of NAVA ($n = 15$)

	NAVA day 1	NAVA day 2	NAVA day 3	*P* value
NAVA level ($cmH_2O/\mu V$)	2.6 (1.2)	1.8 (0.9)*	1.2 (0.6)*	0.003
$EAdi_{maxSBT}$ (μV)	15.5 (9.7)	22.2 (11.7)	23.6 (12.4)	0.130
EAdi (μV)	9.5 (5.4)	11.9 (7.1)	14.0 (6.9)	0.225
Pi_{max}-PEEP (cmH_2O)	20 (8)	17 (10)	15 (9)	0.336
VT (ml)	396 (63)	394 (74)	426 (104)	0.552
VT (ml/kg of IBW)	6.7 (1.3)	6.6 (1.4)	7.4 (1.8)	0.911
RF (cycles/min)	29 (7)	27 (8)	26 (5)	0.455
PEEP (cmH_2O)	6 (2)	6 (2)	5 (2)	0.386
pH	7.45 (0.07)	7.47 (0.06)	7.45 (0.04)	0.713
$PaCO_2$ (mmHg)	39.8 (4.6)	38.5 (5.5)	39.0 (6.4)	0.806
PaO_2/FiO_2	224 (101)	251 (108)*	301 (105)	0.189

Table 4 Comparison between day 1 and day of extubation ($n = 12$)

	NAVA day1	NAVA extubation day	*P* value
NAVA level ($cmH_2O/\mu V$)	2.4 (1.0)	1.0 (0.7)	<0.00001
$EAdi_{maxSTB}$ (μV)	16.6 (9.6)	21.7 (10.3)	0.013
EAdi (μV)	10.0 (5.5)	15.1 (9.2)	0.026
Pimax-PEEP (cmH_2O)	20 (8)	10 (5)	0.003
VT (ml)	402 (65)	421 (93)	0.391
VT (ml kg^{-1} of IBW)	6.9 (1.3)	7.2 (1.5)	0.552
RF (cycles/min)	29 (8)	26 (5)	0.147
pH	7.45 (0.07)	7.46 (0.04)	0.938
$PaCO_2$	39.5 (4.8)	39.7 (5.7)	0.873
PaO_2/FiO_2	233 (107)	275 (106)	0.123

Conclusion: These results suggest that daily titration of NAVA level with an electrical goal of ~60% $EAdi_{maxSBT}$ is feasible and well tolerated. The respiratory mechanics improvement and increase in respiratory drive allowed for a daily reduction of the NAVA level while preserving breathing, oxygenation, and alveolar ventilation until extubation.

NAVA and Sleep

Delisle *et al. Annals of Intensive Care* 2011, 1:42
http://www.annalsofintensivecare.com/content/1/1/42

Annals of Intensive Care
a SpringerOpen Journal

RESEARCH Open Access

Sleep quality in mechanically ventilated patients: comparison between NAVA and PSV modes

Stéphane Delisle[1,2,3*], Paul Ouellet[3,4,5], Patrick Bellemare[1], Jean-Pierre Tétrault[3] and Pierre Arsenault[3]

Table 3 Comparison of sleep quality between the ventilatory modes

	PSV	NAVA	*p*
Stage 1, %	7.5 [4-15]	4 [3-5]	0.006*
Stage 2, %	68 [66-75]	55 [52-58]	0.001*
Stage 3 and 4, %	16.5 [17-20]	20.5 [16-25]	0.001*
REM, %	4.5 [3-11]	16.5 [13-29]	0.001*
→ Fragmentation index, (n/h)	33.5 [25-54]	17.5 [8-21.5]	0.001*
→ Sleep efficacy, %	44 [29-73.5]	73.5 [52.5-77]	0.001*

PSV = pressure support ventilation; NAVA = neurally adjusted ventilatory assist; REM = rapid eye movement; Fragmentation Index = number of arousals and awakenings per hour of sleep; Sleep efficiency = duration of sleep/total duration of recording.

Values are expressed as median [interquartile range].

*p < 0.05.

N = 14
Matched Ve

NAVA and Lower Airway Pressure

A prospective crossover comparison of neurally adjusted ventilatory assist and pressure-support ventilation in a pediatric and neonatal intensive care unit population*

Cormac Breatnach, MRCPI;[1] Niamh P. Conlon, FCARCSI;[1] Maria Stack, MRCPI; Martina Healy, FFARCSI; Brendan P. O'Hare, MRCPI, FFARCSI

Pediatr Crit Care Med 2010 Vol. 11, No. 1

Table 1. Patient characteristics and sedation

Patient No.	Gender	Age	Weight, kg	Diagnosis	Pao_2/Fio_2	Analgesia, μg/kg/h	Sedation μg/kg/h
1	M	9 mos	8.7	Hypoplastic left heart	122	Morphine 36	—
2	M	9 mos	7.5	Tetralogy of Fallot	185	Morphine 40	—
3	F	14 mos	9.4	Pseudomonas Meningitis	555	Morphine 32	Midazolam 60
4	F	22 days	2.7	TGA	299	Morphine 20	—
5	M	4 days	3.2	Post Coarctation repair	264	Morphine 20	—
6	M	7 days	3.9	Cardiomyopathy	150	—	—
7	M	8 days	3.3	Critical aortic stenosis	324	Morphine 8	—
8	M	2 days	3.3	Diaphragmatic hernia	260	Morphine 12	—
9	M	4 yrs	13.7	Hemolytic anemia	167	Morphine 8	—
10	F	14 days	2.8	Transposition of the great arteries	80	Morphine 20	—
11	F	2 mos	2.4	Hypoplastic left heart	315	Morphine 12	—
12	F	2 mos	3.8	Hypoplastic left heart	195	Morphine 40	—
13	F	14 days	4.0	Hypoplastic left heart	237	Morphine 8	—
14	F	2 yrs	10	Cardiomyopathy	378	Morphine 60	—
15	M	9 mos	4.8	Pneumonia	295	Morphine 12	Midazolam 200
16	M	3 yrs	15	Acute respiratory distress syndrome	231	Remifentanil 66	—

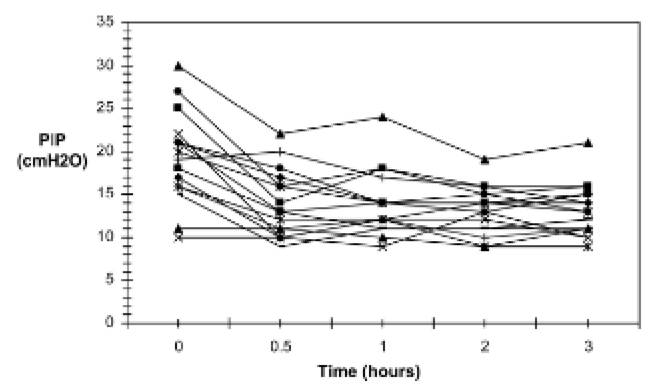

Figure 1. Changes in individual patient peak inspiratory pressure (*PIP*) following commencement of neurally adjusted ventilatory assist (0 hr) after an initial 30-min period of pressure-support ventilation.

Neurally adjusted ventilatory assist in children: An observational study

Jan A. Bengtsson, MD, PhD; Karl Erik Edberg, MD, PI

Pediatr Crit Care Med 2010 Vol. 11, No. 2

Table 3. Patient characteristics and ventilatory times

N	Gender	Age	Ventilator (day)	Diagnosis	NAVA Ventilation (hr)
1	M	2 days	1	Op anal atresia, VSD+ASD	2
2	M	1 mos	2	Op small bowel resection	2.5
3	F	15 yrs	13	Pneumonia	8
4	M	1 mo	38	Op DORV, AVSD, CoA	6.5
5	F	20 days	2	Truncus com., CoA, ICH	5.5
6	F	8 days	3	Op HLHS Norwood I	4
7	M	4 yrs	0	Op TCPC	1
8	F	15 days	3	Op DORV, TGA, VSD	2.5
9	M	18 mos	6	Op brain tumor	6.5
10	F	2.5 mos	1	Op lobar emphysema	1.5
11	M	11 days	5	Op disrupt aortic arch, VSD	8
12	F	2.5 yrs	1	Reop CDH	2.5
13	F	10 mos	2	Op VSD, PA, MAPCA	4
14	F	7 mos	2.5	Op VSD, PDA; Down	2.5
15	M	9 mos	1	Op PDA	0
16	F	3 mos	1.5	Op VSD	1.5
17	M	2 wks	4	Op Truncus com.	2
18	M	4.5 mos	1	Op AVSD	1
19	F	10 mos	7	MI, pulmonary edema	1.5
20	M	32 days	32	AS, cardiomyopathy	2
21	F	2 mos	60	Op HLHS Norwood I	1.5

AS, aortic stenosis; ASD, atrial septal defect; AVSD, atrioventricular septal defect; CDH, congenital diaphragmatic hernia; CoA, coarctation of the aorta; DORV, double outlet right ventricle; HLHS, hypoplastic left heart syndrome; ICH, intracranial haemorrhage; M, mitral insufficiency; MAPCA, major aortopulmonary collateral arteries; Op, operation; PA, pulmonary atresia; PDA, persistent ductus arteriosus; TCPC, total cavopulmonary connection; TGA, transposition of the great arteries; Truncus com., truncus arteriosus; VSD, ventricular septal defect.

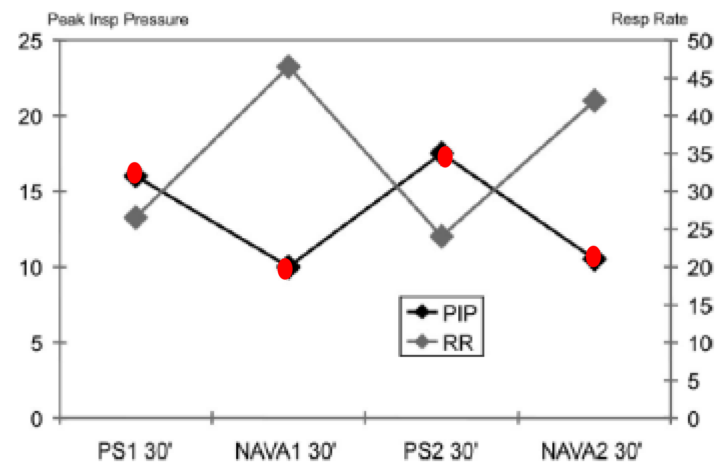

Figure 3. Peak airway pressure and respiratory rate during pressure support and neurally adjusted ventilatory assist (*NAVA*) ventilation. Median values. *Peak Insp Pressure*, peak inspiratory pressure (*PIP*); *Resp Rate*, respiratory rate (*RR*); *PS*, pressure support.

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ORIGINAL ARTICLES

Neurally Adjusted Ventilatory Assist in Neonates Weighing <1500 Grams: A Retrospective Analysis

Howard Stein, MD, and Diane Howard, RRT

J Pediatr, 2012 May;160(5):786-9

Table IV. Ventilatory parameters and blood gases on SIMV-PC and on NAVA in neonates weighing <1500 g

	SIMV-PC	NAVA 1 hour	NAVA 4 hours	NAVA 12 hours	NAVA 24 hours
PIP, cm H_2O	17.4 ± 3	13.6 ± 4.1	13.4 ± 3.8	13.3 ± 4.1	12.6 ± 3.6*
FiO_2	0.32 ± 0.12	0.27 ± 0.07	0.25 ± 0.07	0.26 ± 0.07	0.28 ± 0.07*
RR, bpm	53 ± 12	55 ± 17	56 ± 16	55 ± 14	59 ± 15
MAP, cm H_2O	8.7 ± 1.5	7.6 ± 1.9	8.1 ± 2.1	8.3 ± 2.1	8 ± 1.5
pH (all)	7.34 ± 0.08	7.35 ± 0.05			7.36 ± 0.05
pH ≤7.35	7.29 ± 0.05	7.32 ± 0.04			7.34 ± 0.5*
pH >7.35	7.42 ± 0.04	7.39 ± 0.03			7.4 ± 0.5
pCO_2 (all), Torr	47 ± 10	46 ± 7			45 ± 6
pC02 ≥45	54 ± 7	50 ± 6			47 ± 4*
pCO <45	38 ± 5	41 ± 6			41 ± 5

*$P < .05$ difference from SIMV-PC by Hotelling's T^2 test for repeated measures.

N = 52
Mean BW = 837 g
Mean age = 15 days
GA at birth: 26 wks
Study weight = 958 g

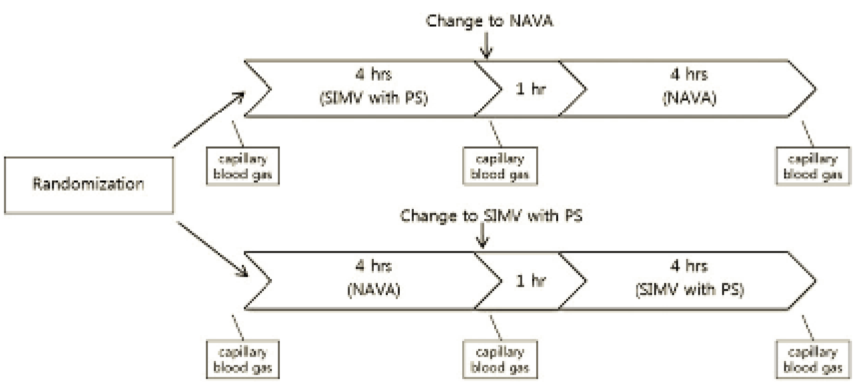
THE JOURNAL OF PEDIATRICS • www.jpeds.com

ORIGINAL ARTICLES

Randomized Crossover Study of Neurally Adjusted Ventilatory Assist in Preterm Infants

J Pediatr ,2012 Nov;161(5):808-13

Juyoung Lee, MD, Han-Suk Kim, MD, PhD, Jin A Sohn, MD, Jin A Lee, MD, PhD, Chang Won Choi, MD, PhD, Ee-Kyung Kim, MD, PhD, Beyong Il Kim, MD, PhD, and Jung-Hwan Choi, MD, PhD



N = 19
Mean study weight = 1210 g
Mean age = 7 days
GA at birth: 29 wks

Table III. Ventilator parameters and blood gases during each ventilatory period for SIMV with PS and NAVA

	SIMV with PS (n = 19)	NAVA (n = 19)	*P* value
Monitored ventilator parameters			
PEEP, mean ± SD, cm$H_2$0	5.8 ± 0.7	5.9 ± 0.6	.20*
PIP, mean ± SD, cm$H_2$0	13.5 ± 3.4	12.5 ± 2.7	.04*
MAP, mean ± SD, cm$H_2$0	8.0 ± 1.3	8.0 ± 1.2	.25*
Mv, mean ± SD, L/min/kg	0.53 ± 0.15	0.51 ± 0.11	.26*
TV/kg, mean ± SD, mL/kg	8.7 ± 2.1	8.5 ± 2.2	.60*
Dynamic compliance, mean ± SD, mL/cm$H_2$0	1.70 ± 0.5	1.8 ± 0.4	.09*
WOB, median (range), mJ/L	11.1 (3.9-61)	8.4 (1.6-30)	.002†
$EAdi_{peak}$, mean ± SD, uV	13.4 ± 5.7	11.4 ± 5.5	.004*
FiO_2, median (range), %	23 (21-41)	23 (21-39)	.31†
RR, mean ± SD, /min	54 ± 9	53 ± 11	.23*
TV/$EAdi_{peak}$, mean ± SD, mL/uV	1.0 ± 0.6	1.3 ± 0.7	.003*
TV/$EAdi_{peak}$/kg, mean ± SD, mL/uV/kg	0.77 ± 0.39	0.99 ± 0.66	.02*
PIP/$EAdi_{peak}$, mean ± SD, cm$H_2$0	1.18 ± 0.56	1.40 ± 0.74	.02*
Capillary blood gas analysis			
pH, mean ± SD	7.33 ± 0.05	7.33 ± 0.05	.52*
pCO_2, mean ± SD, Torr	47 ± 7	47 ± 8	.95*
pO_2, mean ± SD, Torr	39 ± 9	38 ± 8.51	.71*
Base excess, mean ± SD, mmol/L	−2 ± 4	−1 ± 4	.24*
HCO_3, mean ± SD, mmol/L	24 ± 4	25 ± 4	.60*
Total CO_2, mean ± SD, mmol/L	26 ± 4	26 ± 4	.59*

MAP, mean airway pressure; *Mv*, minute ventilation.
*Paired *t* test.
†Wilcoxon signed-rank test.

ORIGINAL ARTICLE

Prospective crossover comparison between NAVA and pressure control ventilation in premature neonates less than 1500 grams

H Stein[1], H Alosh[2], P Ethington[1] and DB White[3]

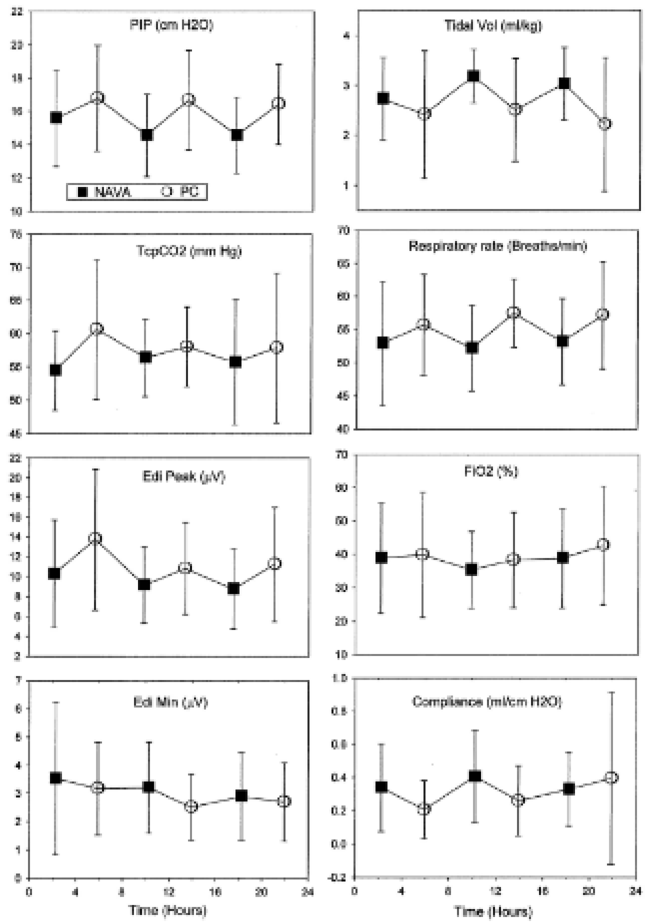


Figure 1. Mean values (±s.d.) averaged over 4h for each measured variable over time as the patient was changed back and forth between NAVA and PCV. All variables were statistically different ($P<0.05$). PIP, peak inspiratory pressure; $TcpCO_2$, transcutaneous PCO_2; TV, tidal volume.

Table 1. Mean value (±s.d.) for each measured variable overall on NAVA versus PCV

	NAVA	*PCV*
PIP (cm H_2O)	14.9±2.6	16.6±2.9[a]
$TcpCO_2$ (mm Hg)	55.5±7.2	58.8±9.5[a]
TV (ml kg^{-1})	3±0.7	2.4±1.2[a]
TV range (ml kg^{-1})	0.2–13.4	0.1–8.6
Compliance (ml per cmH_2O)	0.36±0.25	0.29±0.34[a]
RR (breaths per min)	52.7±7.5	56.7±7.1[a]
Edi peak (µv)	9.4±4.5	11.9±6[a]
Edi min (µv)	3.2±2	2.8±1.4[a]
FiO_2 (%)	37.6±14.4	40.3±17[a]
MAP (cm H_2O)	9.4±1.1	9.3±1

Abbreviations: MAP, mean airway pressure; PIP, peak inspiratory pressure; RR, respiratory rate; $TcpCO_2$, transcutaneous PCO_2; TV, expiratory tidal volume. [a]$P<0.05$.

N = 5
GA = 26.2 wks
BW = 697 g
Study weight = 850 g
Age at study = 24

Intensive Care Med
DOI 10.1007/s00134-009-1626-x

EXPERIMENTAL

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Thomas G. Parker
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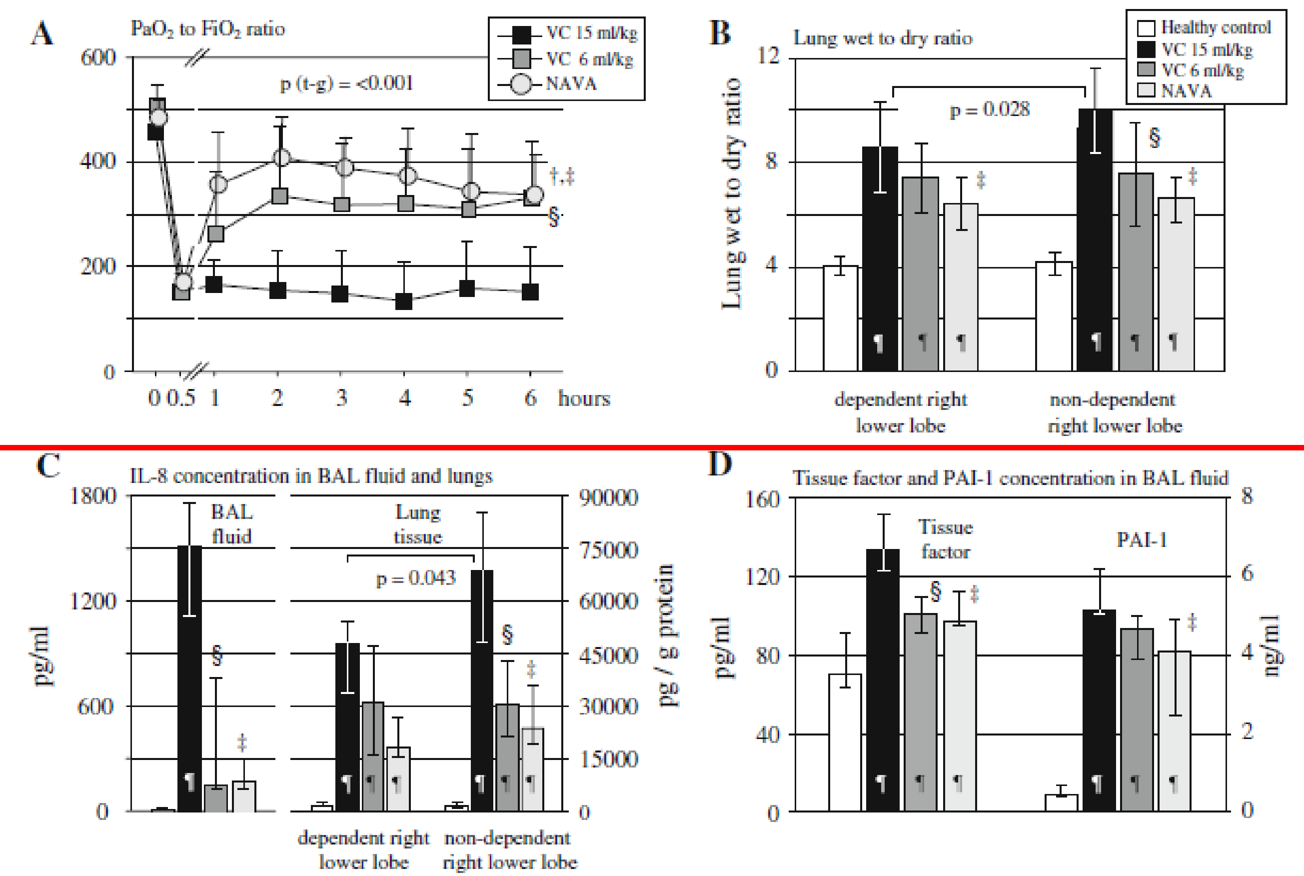
Haibo Zhang
Arthur S. Slutsky

Neurally adjusted ventilatory assist decreases ventilator-induced lung injury and non-pulmonary organ dysfunction in rabbits with acute lung injury



Intensive Care Med. 2009 Nov;35(11):1979-89

Anesthesiology 2010; 113:925–35

Neurally Adjusted Ventilatory Assist in Critically Ill Postoperative Patients: A Crossover Randomized Study

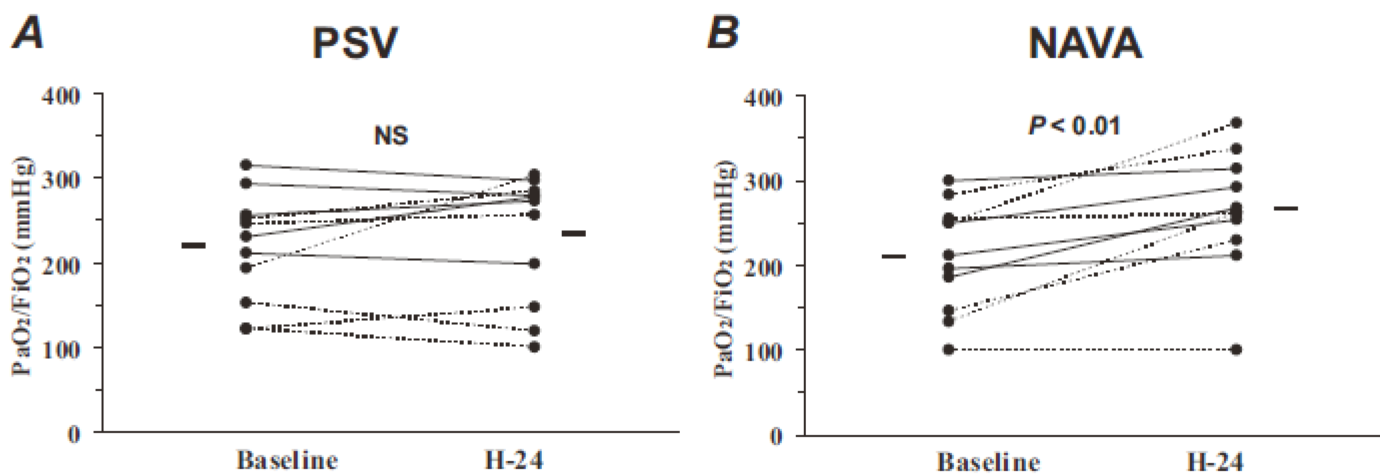
Yannael Coisel, M.D.,* Gerald Chanques, M.D.,† Boris Jung, M.D.,† Jean-Michel Constantin, M.D., Ph.D.,‡
Xavier Capdevila, M.D., Ph.D.,§ Stefan Matecki, M.D., Ph.D.,|| Salvatore Grasso, M.D., Ph.D.,#
Samir Jaber, M.D., Ph.D.**

Table 3. Gas Exchange

Parameters	PSV (n = 11)	NAVA (n = 11)
pH	7.45 ± 0.06	7.44 ± 0.06
Pa_{CO_2}, mmHg	41 ± 9	39 ± 7
Pa_{O_2}, mmHg	108 ± 27	117 ± 32
HCO_3^-, mM	29 ± 7	27 ± 6
Sa_{O_2}, %	98 ± 2	98 ± 2
Pa_{O_2}/FI_{O_2}, mmHg	230 ± 75	264 ± 71*

Data are presented as mean ± SD.
* $P < 0.05$ significantly different from the value

N = 11 surgical Adult ICU
24 h NAVA vs 24 h PSV

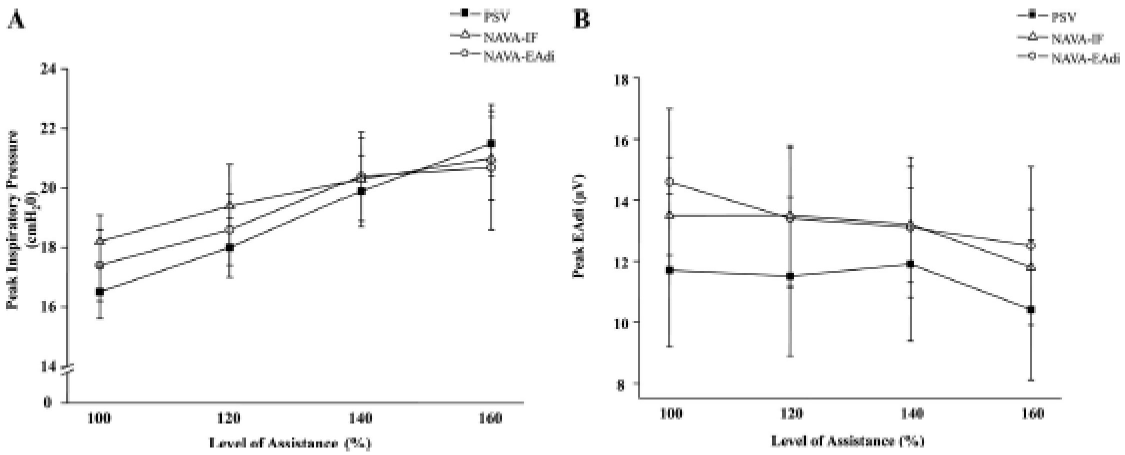


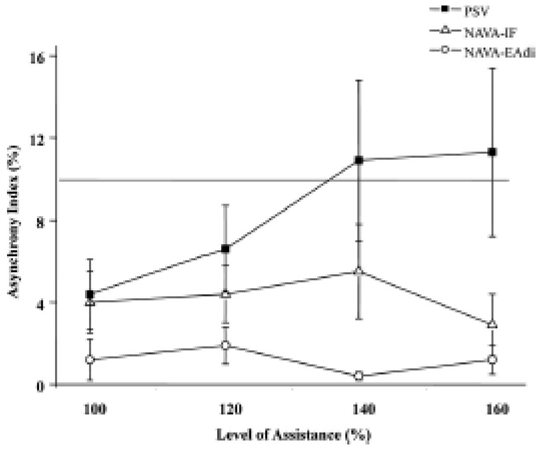
NAVA in ARDS

Neurally adjusted ventilatory assist in patients recovering spontaneous breathing after acute respiratory distress syndrome: Physiological evaluation

Nicolas Terzi, Iris Pelieu, Lydia Guittet, Michel Ramakers, Amélie Seguin, Cédric Daubin, Pierre Charbonneau, Damien du Cheyron, Frédéric Lofaso

Crit Care Med 2010 Vol. 38, No. 9





N = 11 ARDS (weaning phase)
PSV, NAVAflow, NAVAedi
Conclusion: NAVA limits risk of over-assistance

Intensive Care Med
DOI 10.1007/s00134-012-2755-1

ORIGINAL

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Giacomo Grasselli
Andrea Confalonieri
Roberto Rona
Nicolo' Patroniti
Antonio Pesenti

Patient–ventilator interaction in ARDS patients with extremely low compliance undergoing ECMO: a novel approach based on diaphragm electrical activity

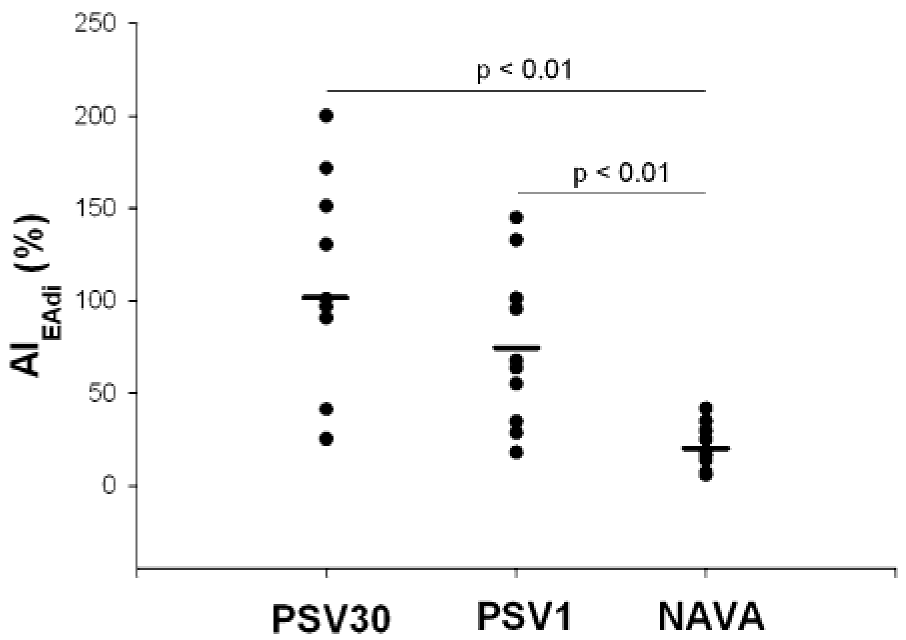

Fig. 3 EAdi-based AI (AI_{EAdi}) significantly decreased during NAVA. AI_{EAdi} = number of EAdi-based asynchrony events/number of positive EAdi deflections × 100. *Horizontal solid lines* represent mean values. *p* values refer to differences between PSV30 or PSV1 and NAVA (Tukey method)

NAVA and CHD

The Journal of Maternal-Fetal and Neonatal Medicine, 2012; Early Online: 1–5

ISSN 1476-7058 print/ISSN 1476-4954 online
DOI: 10.3109/14767058.2012.745502

informa
healthcare

ORIGINAL ARTICLE

Neurally adjusted ventilatory assist in weaning of neonates affected by congenital diaphragmatic hernia

Andrea Gentili[1], Francesca Masciopinto[1], Maria C. Mondardini[1], Stefania Ansaloni[1], Maria L. Bacchi Reggiani[2] & Simonetta Baroncini[1]

Table III. Analysis of A-aDO_2, PaO_2/FiO_2, $PaCO_2$, PIP, MVE, RR, HR, MAP at PSV mode time point 3 h before NAVA start, 3, 12, 24 h after the start of NAVA ventilation: comparison between PSV and NAVA.

Parameters	PSV	3 h NAVA	12 h NAVA	24 h NAVA	Friedman test
A-aDO_2 (mm Hg)	91.5 ± 37.2	48.4 ± 4.7*	44.8 ± 27.6*	36.9 ± 19.3*	$p = 0.002$
	112 (25–131)	46 (19–89)	51 (7–89)	35 (6–65)	
PaO_2/FiO_2 (mm Hg)	259.8 ± 87.3	387.4 ± 73.1*	382.5 ± 74.6*	457.1 ± 66.5*	$p = 0.002$
	217 (196–465)	380 (287–483)	363 (282–490)	426 (410–571)	
$PaCO_2$ (mm Hg)	52.6 ± 8.1	43.2 ± 10.5	41.3 ± 8.1*	40.9 ± 8.1*	$p = 0.001$
	53 (40–67)	41 (27–57)	38 (31–59)	38 (30–54)	
PIP (cmH_2O)	14.4 ± 3.2	11.6 ± 3.4	11.3 ± 3.4*	10.4 ± 3.0*	$p = 0.002$
	15 (9–19)	13 (7–18)	12 (6–17)	10 (6–15)	
MVE (L/min)	1.44 ± 0.21	1.43 ± 0.33	1.59 ± 0.25	1.63 ± 0.31	n.s.
	1.6 (1.1–1.8)	1.6 (1–2)	1.6 (1–1.9)	1.7 (1.1–2.2)	
RR (bpm)	52.8 ± 7.3	51.5 ± 11.1	46.9 ± 4.3	52.1 ± 8.9	n.s.
	55 (42–63)	48 (36–68)	47 (41–55)	48 (38–66)	
HR (bpm)	140.7 ± 5.2	142.6 ± 10.7	144.7 ± 5.9	145.7 ± 6.9	n.s.
	140 (135–150)	140 (130–160)	145 (135–150)	145 (134–160)	
MAP (mm Hg)	52.9 ± 4.6	50.9 ± 5.4	51.7 ± 4.7	51.8 ± 4.9	n.s.
	52 (45–60)	49 (45–60)	53 (46–58)	51 (45–59)	

The data are expressed as mean and SD (top line) and median and range (bottom line).
A-aDO_2, alveolar-arterial O_2 gradient; HR, heart rate (bpm, beats per minute); MAP, mean arterial pressure; MVE, expired minute volume; PIP, peak inspiratory pressure; RR, respiratory rate (bpm, breaths per minute).
*$p < 0.05$ vs the time of the PSV mode.

NAVA and ECMO

Intensive Care Med
DOI 10.1007/s00134-010-1982-6

ORIGINAL

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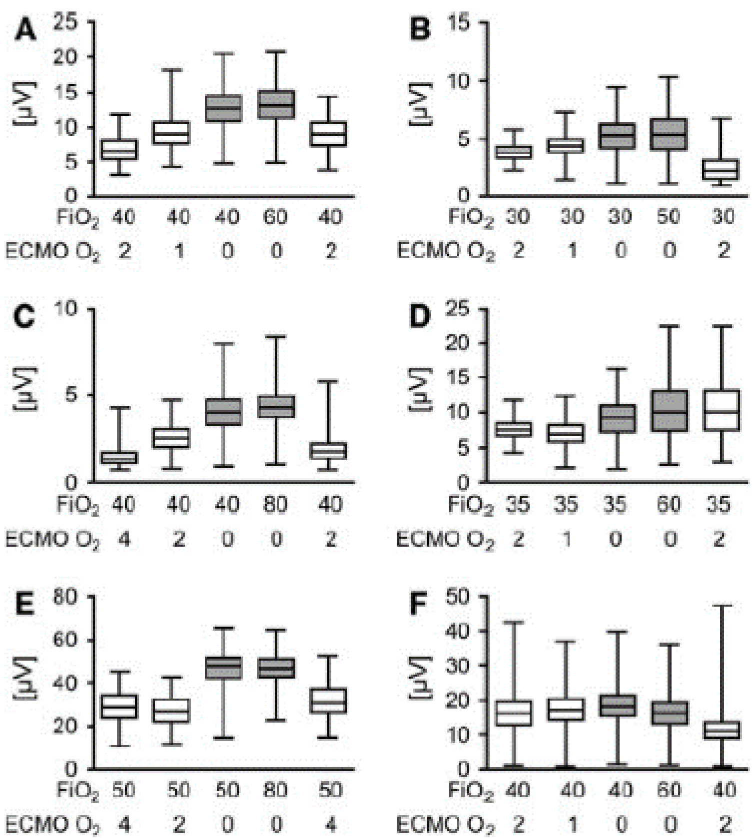
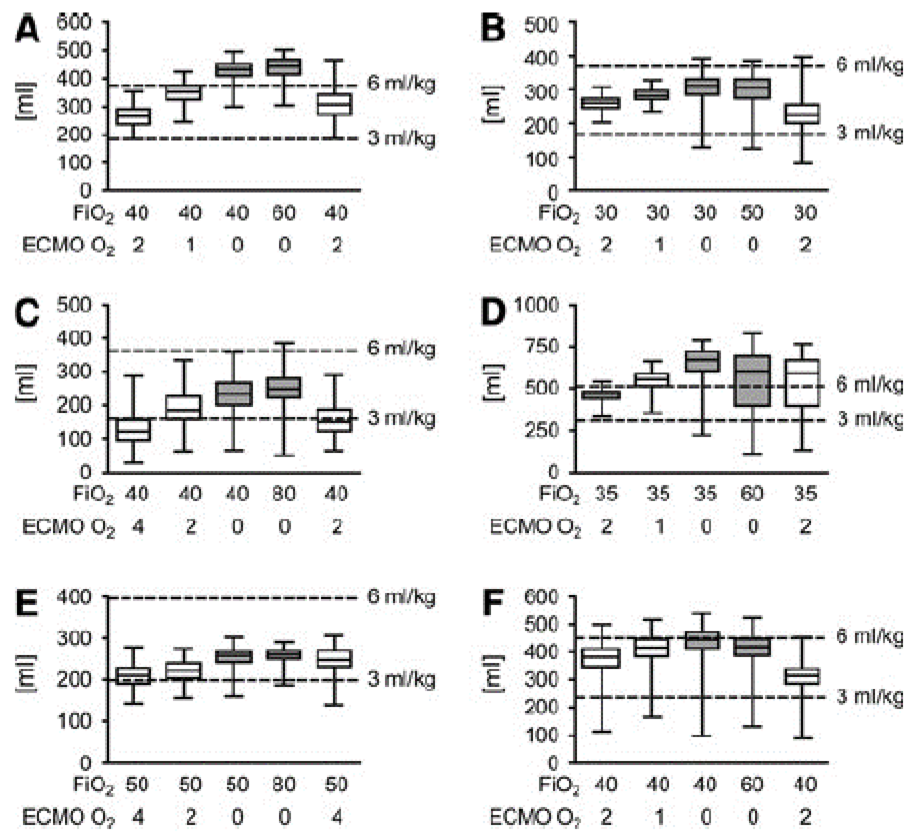
Matthias Lubnow
Alois Philipp
Guenter A. J. Riegger
Christof Schmid
Michael Pfeifer
Thomas Mueller

Autoregulation of ventilation with neurally adjusted ventilatory assist on extracorporeal lung support

N = 6 adult bilateral pneumonia





NAVA and Lung Aeration

Intensive Care Med
DOI 10.1007/s00134-013-2898-8

ORIGINAL

Paul Blankman
Djo Hasan
Martijn S. van Mourik
Diederik Gommers

Published online: 04 April 2013

Ventilation distribution measured with EIT at varying levels of pressure support and Neurally Adjusted Ventilatory Assist in patients with ALI

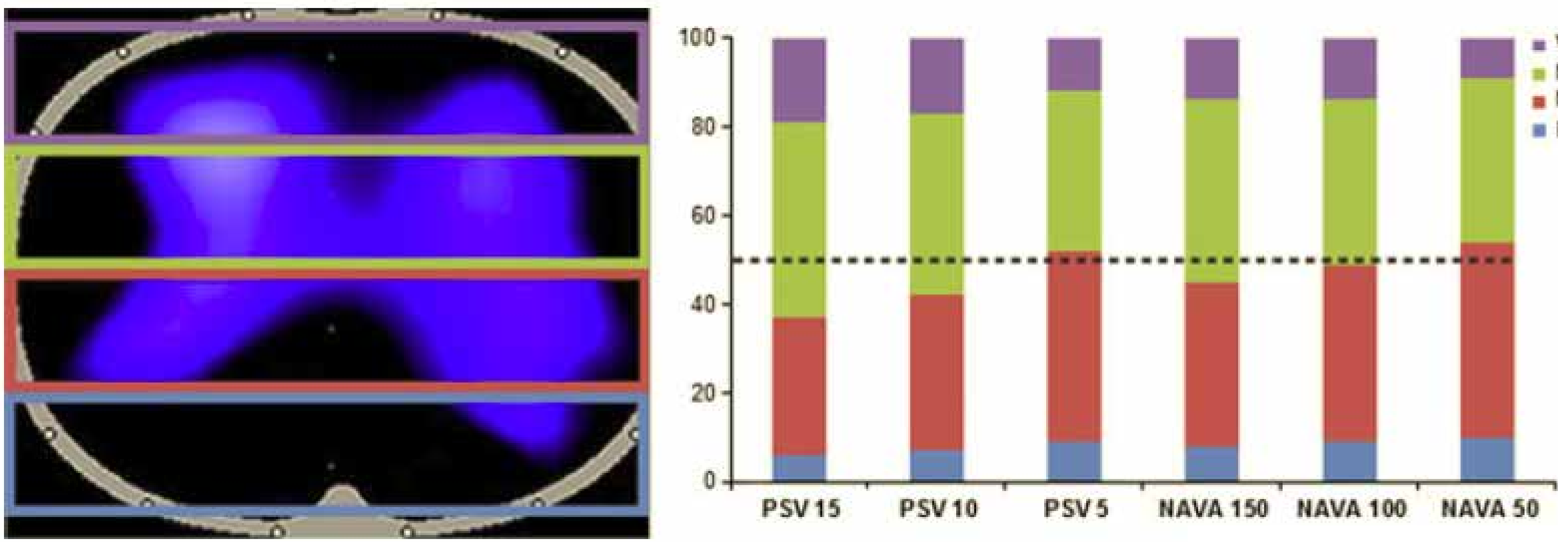


Fig. 1 Impedance distribution. The EIT image is divided in four regions of interest (*purple* ventral, *green* mid-ventral, *red* mid-dorsal, *blue* dorsal). The *bars* on the right side represent the percentage of the total tidal impedance variation located in each region, for each assist level. The *dashed-line* represents the 50 % border

Intensive Care Med
DOI 10.1007/s00134-013-2898-8

ORIGINAL

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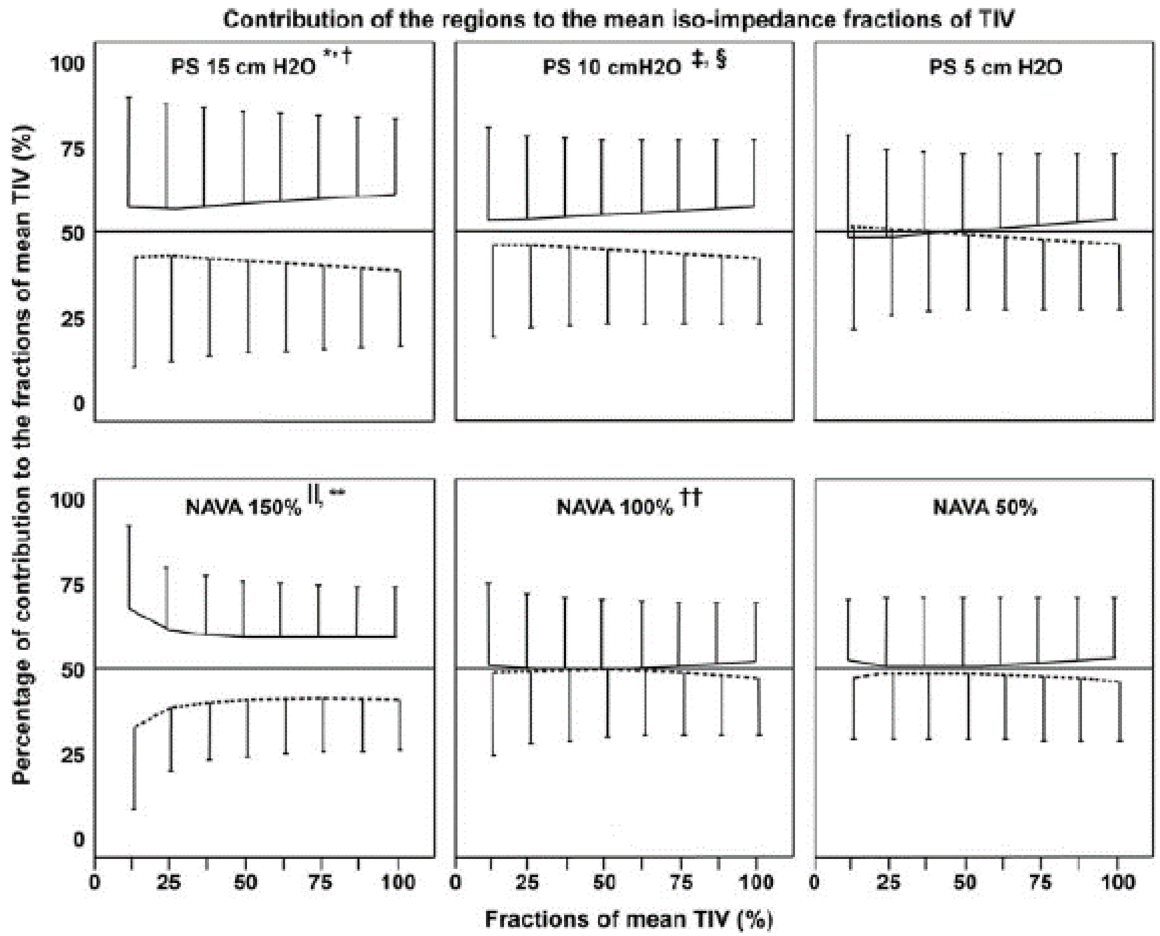

NIV-NAVA

Intensive Care Med
DOI 10.1007/s00134-012-2626-9

ORIGINAL

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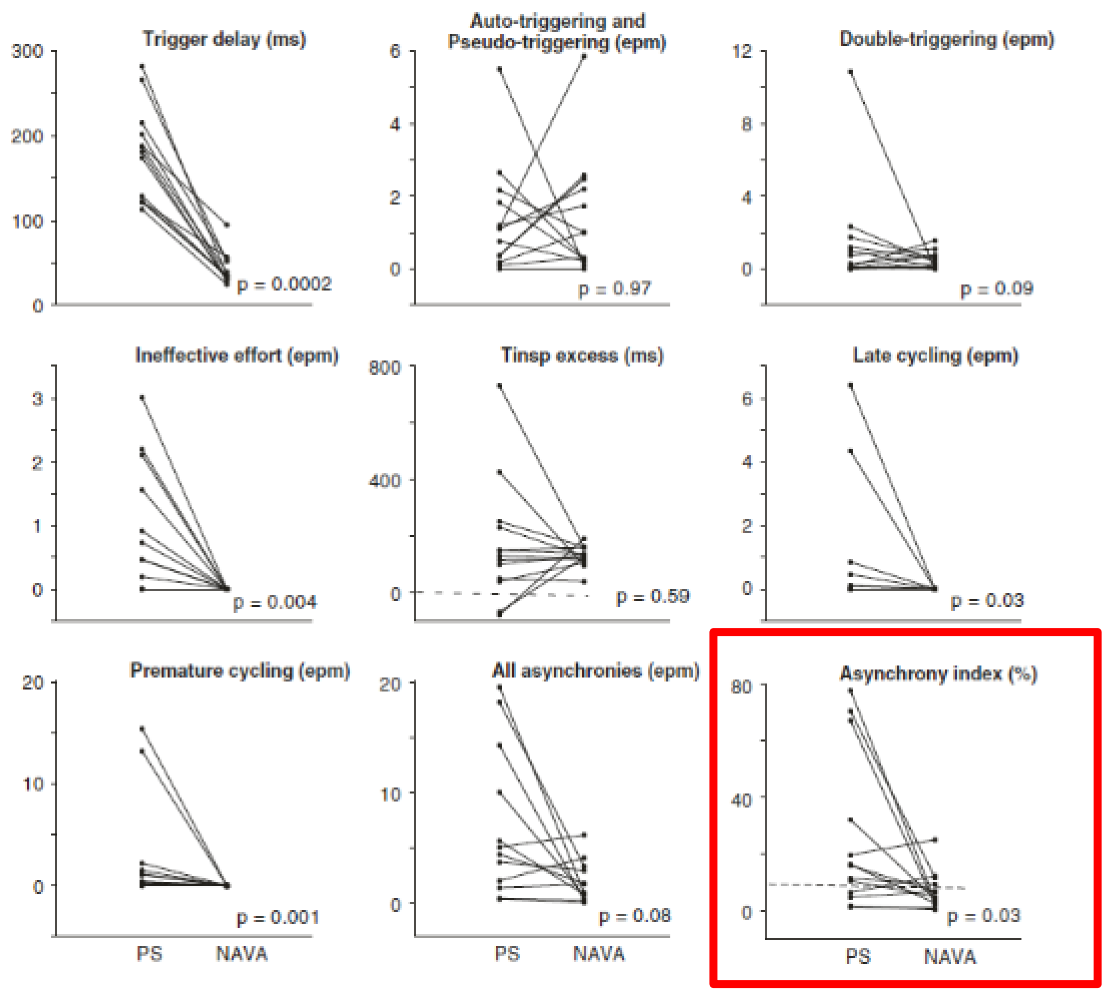
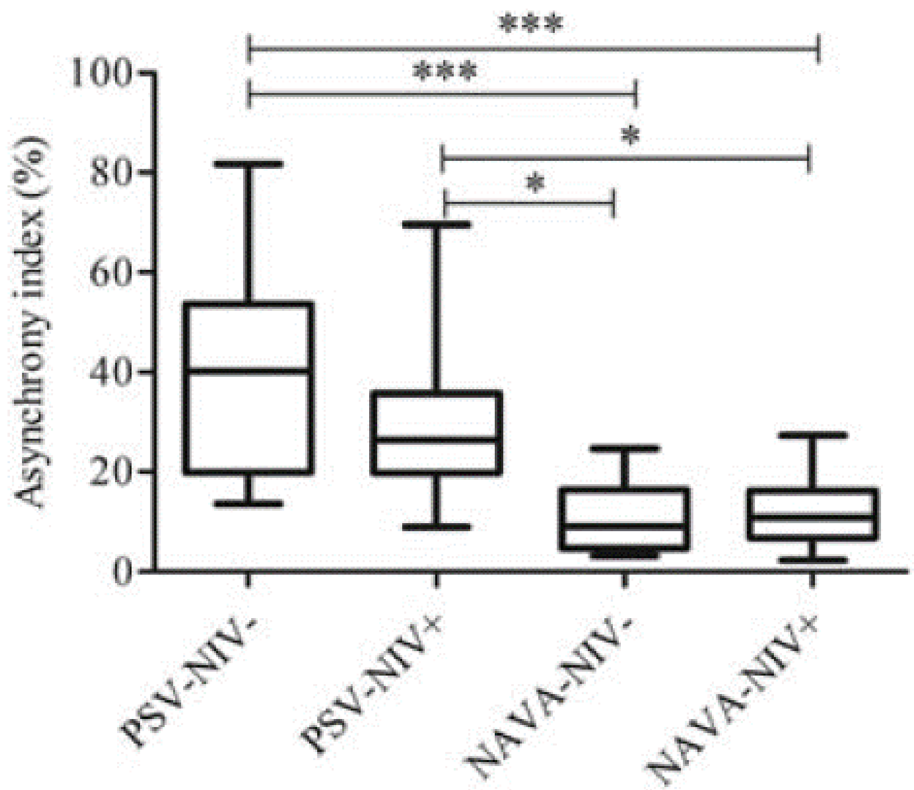
Neurally adjusted ventilatory assist (NAVA) improves patient–ventilator interaction during non-invasive ventilation delivered by face mask



Neurally adjusted ventilatory assist improves patient–ventilator interaction during postextubation prophylactic noninvasive ventilation*

Matthieu Schmidt, MD; Martin Dres, MD; Mathieu Raux, MD, PhD; Emmanuelle Deslandes-Boutmy, MD;
Felix Kindler, MD; Julien Mayaux, MD; Thomas Similowski, MD, PhD; Alexandre Demoule, MD, PhD

(Crit Care Med 2012; 40:1738–1744)



Review Article

Interest of Monitoring Diaphragmatic Electrical Activity in the Pediatric Intensive Care Unit

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Received 20 July 2012; Revised 15 January 2013; Accepted 21 January 2013

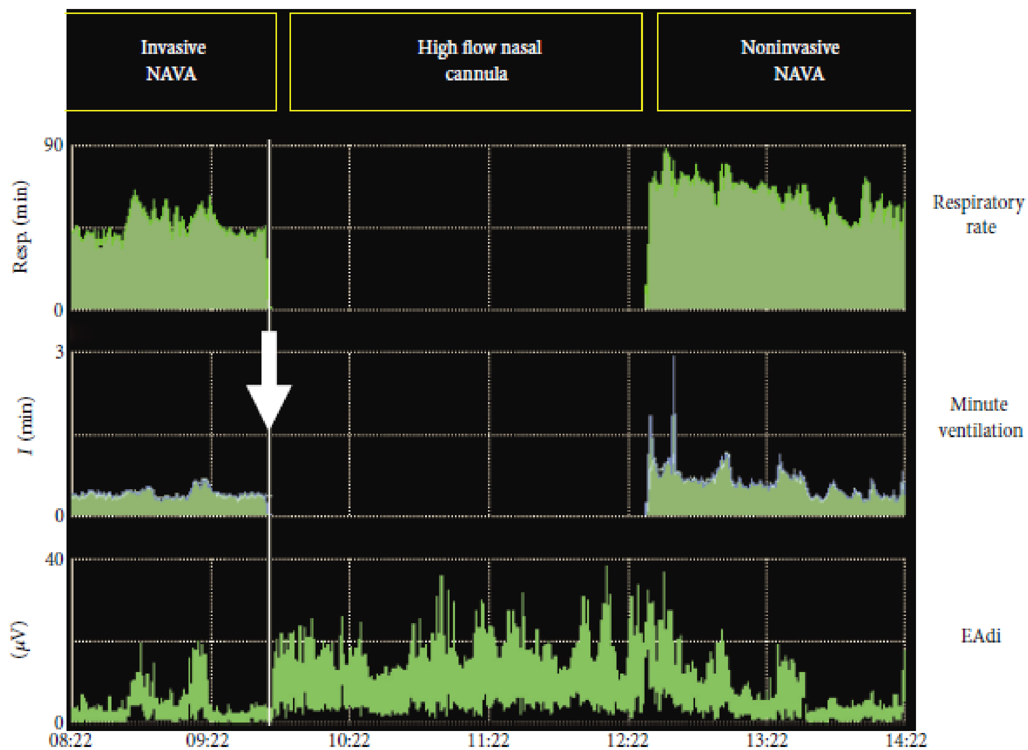

Figure 3: Evolution of respiratory rate, minute ventilation, and EAdi in a 15-day-old girl in the postoperative period of aortic valvotomy. After extubation (arrow), the infant was immediately supported with high flow nasal cannula. Progressive respiratory failure led to the introduction of noninvasive ventilation with NAVA 3 hours after extubation. An increase in EAdi was evident shortly after extubation, prior to the onset of clinical respiratory distress. The improvement of the respiratory failure with noninvasive ventilation was rapidly followed by a decrease in EAdi, toward preextubation levels.

Summary

Edi Monitoring

- Edi catheter positioning method is valid if you follow the steps recommended (4 studies)
- Published mean Edipk values (24 studies, 482 patients) are consistently in the range of 10-15 uV (range 4-33 uV) under NAVA
- Edi monitoring is useful for:
  - Detecting asynchrony (>10 studies)
  - Detecting use of diaphragm (VIDD)
  - Detecting apnea, diagnostic tool, evaluation of therapy
  - Monitor unloading (>10 studies)
  - Monitor extubation readiness (2 studies)
  - Trend neural breathing pattern (edi pk, edi min, nrr, nti) >24 studies

NAVA

- NAVA Ventilation Findings
  - Improves patient-ventilator interaction (timing and proportionality) in all ages (>20 studies)
  - Reduces central apnea
  - Improves sleep quality
  - Less distress
  - Better lung aeration
  - Feasible at all periods of disease process (incl ARDS)
  - Improves oxygenation
  - Lower PIP (self-weaning?)
- NAVA is neurally integrated
  - H-B reflexes (limits VT), responds to CO2
  - Lung protection?
- NAVA level can be set
  - Overlay/preview to match pressure (>8 papers)
  - Titration (>5 papers)
  - Target Edi (1 study)
  - Target Vt (>3 studies)
  - Target comfort
  - Most levels 0.5-2.0 cm H2O per uV (24 studies373 patients)
  - VT Adult 6.8 ml/kg (5.9-9.9), infant 6.4 ml/kg (5.3-8.7) (24 studies373 patients)
  - RR Adult 25 (18-30), infant 46 (35-59) (24 studies373 patients)
- NIV-NAVA
  - Improves synchrony, despite leaks
  - Monitor unloading
  - Integrated with upper airway
  - Freedom of interface

Questions?

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