COMPARISON OF VARIOUS MODES OF WEANING WITH SPECIAL FOCUS ON NAVA

Ankan B

SR PULMONARY MEDICINE

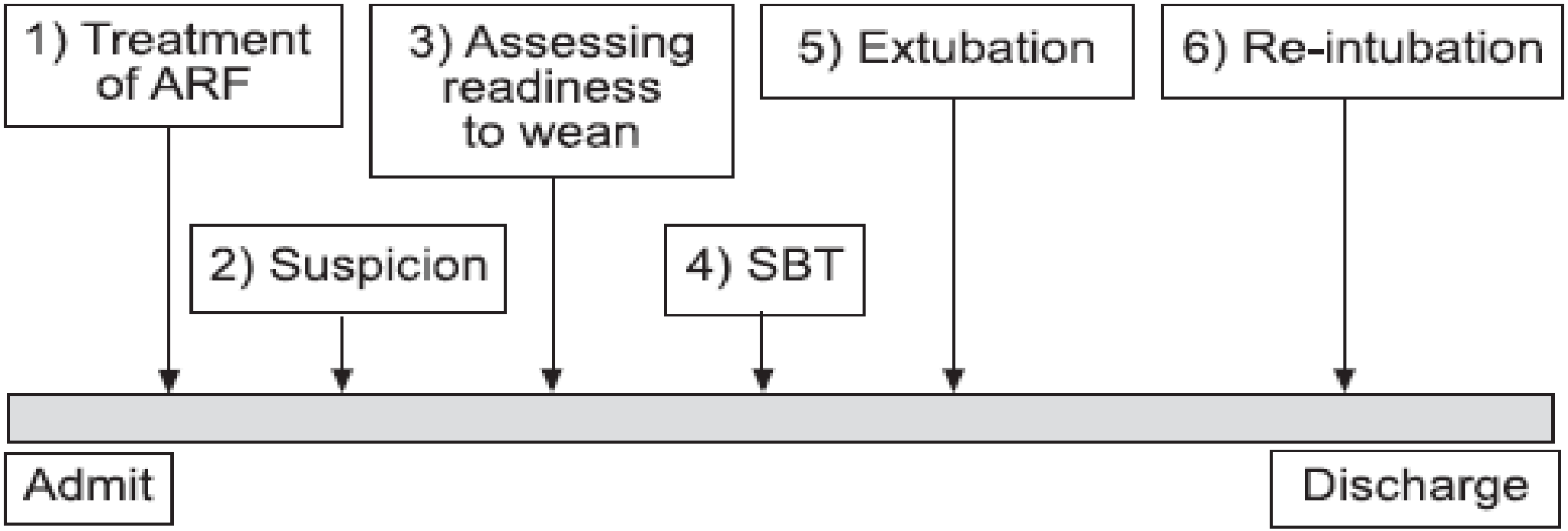


FIGURE 1. Schematic representation of the different stages occurring in a mechanically ventilated patient. ARF: acute respiratory failure; SBT: spontaneous breathing test.

TABLE 1 Definition of the different stages, from initiation to mechanical ventilation to weaning

Stages	Definitions
Treatment of ARF	Period of care and resolution of the disorder that caused respiratory failure and prompted mechanical ventilation
Suspicion	The point at which the clinician suspects the patient may be ready to begin the weaning process
Assessing readiness to wean	Daily testing of physiological measures of readiness for weaning (MIP, f_R/V_T) to determine probability of weaning success
Spontaneous breathing trial	Assessment of the patient's ability to breathe spontaneously
Extubation	Removal of the endotracheal tube
Reintubation	Replacement of the endotracheal tube for patients who are unable to sustain spontaneous ventilation

ARF: acute respiratory failure, MIP: maximal inspiratory pressure, f_R/V_T: respiratory frequency to tidal volume ratio (rapid shallow breathing index).

Weaning covers the entire process of liberating the patient from mechanical support and from the endotracheal tube

The most important steps in the weaning process to prevent unnecessary prolongation of mechanical ventilation are timely recognition of both readiness to wean and readiness to extubate.

Am J Respir Crit Care Med 2011;184(4):430-437

Weaning involves the transition of the work of breathing and control of ventilation from the ventilator to the patient, a little at a time or all at once

Weaning process accounts for nearly 40% of the duration of invasive ventilation.

As costs and complications of invasive mechanical ventilation are substantial, discontinuation at the earliest possible moment is necessary

JAMA 2002;287(3):345-355.

Crit Care Med 2005;33(6):1266-1271

Failure to recognize ventilator withdrawal potential will result in longer stay, higher costs, excessive sedation, longer exposure to potentially “toxic” airway pressures/volumes, and increased infection risk

Premature ventilator withdrawal can lead to airway loss, compromised gas exchange, aspiration, and inspiratory muscle fatigue

A failed extubation is associated with an 8-fold higher odds ratio for nosocomial pneumonia and a 6–12-fold increased mortality risk

Chest 2001;120(6 Suppl):375S-395S

Respir Care 2002;47(1):69-90

Most patients, approximately 60—70%,will require minimal to no weaning of ventilatory supportand are extubated without difficulty after the first SBT .These patients may be classified as simple weaning (gr1)

Remaining 30—40% maybe classified as difficult weaning, defined as requiring upto three SBTs and seven days to achieve weaning success(gr2)

Prolonged weaning defined as requiring more than three SBTs and more than seven days of weaning. These patients require a more graduated approach to reduce the amount of support provided by the ventilator (gr3)

Brochard L. 5th International Consensus Conference in Intensive Care Medicine www.ersnet.org/ers/lr/browse/default.aspx?id52814

TABLE 5 Considerations for assessing readiness to wean

Clinical assessment	Adequate cough
	Absence of excessive tracheobronchial secretion
	Resolution of disease acute phase for which the patient was intubated
Objective measurements	Clinical stability
	Stable cardiovascular status (*i.e.* $f_C \leqslant 140$ beats·min^{-1}, systolic BP 90–160 mmHg, no or minimal vasopressors)
	Stable metabolic status
	Adequate oxygenation
	S_{a,O_2} >90% on $\leqslant F_{I,O_2}$ 0.4 (or $P_{a,O_2}/F_{I,O_2} \geqslant 150$ mmHg)
	PEEP $\leqslant 8$ cmH_2O
	Adequate pulmonary function
	$f_R \leqslant 35$ breaths·min^{-1}
	MIP $\leqslant$ -20– -25 cmH_2O
	V_T >5 mL·kg^{-1}
	VC >10 mL·kg^{-1}
	f_R/V_T <105 breaths·min^{-1}·L^{-1}
	No significant respiratory acidosis
	Adequate mentation
	No sedation or adequate mentation on sedation (or stable neurologic patient)

Data taken from [5, 6, 13, 16–18, 22]. f_C: cardiac frequency; BP: blood pressure; S_{a,O_2}: arterial oxygen saturation; F_{I,O_2}: inspiratory oxygen fraction; P_{a,O_2}: arterial oxygen tension; PEEP: positive end-expiratory pressure; f_R: respiratory frequency; MIP: maximal inspiratory pressure; V_T: tidal volume; VC: vital capacity. 1 mmHg=0.133 kPa.

TABLE 6 Failure criteria of spontaneous breathing trials

Clinical assessment and subjective indices	Agitation and anxiety
	Depressed mental status
	Diaphoresis
	Cyanosis
	Evidence of increasing effort
	Increased accessory muscle activity
	Facial signs of distress
	Dyspnoea
Objective measurements	P_{a,O_2} ⩽50–60 mmHg on F_{I,O_2} ⩾0.5 or S_{a,O_2} <90%
	P_{a,CO_2} >50 mmHg or an increase in P_{a,CO_2} >8 mmHg
	pH <7.32 or a decrease in pH ⩾0.07 pH units
	f_R/V_T >105 breaths·min^{-1}·L^{-1}
	f_R >35 breaths·min^{-1} or increased by ⩾50%
	f_C >140 beats·min^{-1} or increased by ⩾20%
	Systolic BP >180 mmHg or increased by ⩾20%
	Systolic BP <90 mmHg
	Cardiac arrhythmias

TABLE 4 Common pathophysiologies and their incidence, which may impact on the ability to wean a patient from mechanical ventilation

Pathophysiology	Consider
Respiratory load	Increased work of breathing: inappropriate ventilator settings
	Reduced compliance: pneumonia (ventilator-acquired); cardiogenic or noncardiogenic oedema; pulmonary fibrosis; pulmonary haemorrhage; diffuse pulmonary infiltrates
	Airway bronchoconstriction
	Increased resistive load
	During SBT: endotracheal tube
	Post-extubation: glottic oedema; increased airway secretions; sputum retention
Cardiac load	Cardiac dysfunction prior to critical illness
	Increased cardiac workload leading to myocardial dysfunction: dynamic hyperinflation; increased metabolic demand; unresolved sepsis
Neuromuscular	Depressed central drive: metabolic alkalosis; mechanical ventilation; sedative/hynotic medications
	Central ventilatory command: failure of the neuromuscular respiratory system
	Peripheral dysfunction: primary causes of neuromuscular weakness; CINMA
Neuropsychological	Delirium
	Anxiety, depression
Metabolic	Metabolic disturbances
	Role of corticosteroids
	Hyperglycaemia
Nutrition	Overweight
	Malnutrition
	Ventilator-induced diaphragm dysfunction
Anaemia	

Weaning should be considered as early as possible in patients receiving mechanical ventilation

SBT determines if patients can be successfully extubated

The initial SBT should last 30 min and consist of either T-tube breathing or low levels of PS (5–8 cmH2O in adults; 10 cmH2O in paediatric patients) with or without 5 cmH2O PEEP

Concept of routine “spontaneous awakening trials” and routine sedation cessation trials, coupled with routine SBTs markedly accelerate the ventilator withdrawal process.

Lancet 2008;371(9607):126-134

In patients on mechanical ventilation weaning failure occur in 31% of case(range 26–42%)

When initial attempts at spontaneous breathing fail appropriate mode(s) of ventilatory support should be chosen which:

1) Maintain a favorable balance between respiratory system capacity and load

2) Attempt to avoid diaphragm muscle atrophy

3) Aid in the weaning process

N Engl J Med 1996;335: 1864–1869

N Engl J Med 1995; 332: 345–350

Am J Respir Crit Care Med 1994; 150: 896–903

Am J Respir Crit Care Med 1999; 159: 512–518

Spontaneous breathing trial-Multiple studies examined the methodology for performing an SBT

There is no difference in the percentage of patients who pass the SBT/extubated successfully when a T-tube trial is compared with the use of low levels of pressure support (PS), such as 7 cmH2O in adults or 10 cmH2 in paediatric patients, or the use of CPAP

The use of automatic tube compensation (ATC), which adjusts for the assumed resistance of the endotracheal tube, is at least as successful as the use of simple T-tube or low-level PS

Crit Care Med 1997; 25: 567–574

N Engl J Med 1994; 330: 1056–1061

Chest 1991; 100: 1655–1659

Acta Anaesthesiol Scand 2002; 46: 973–979

PRESSURE SUPPORT VENTILATION

PSV is commonly utilized and is the sole mode of mechanical ventilation used during the weaning process in 21% of patients

PSV can be used during an SBT and as a weaning mode in both difficult and prolonged weaning cases

In 130 patients of failed initial SBT, Esteban et al. reported that either one daily trial or multiple daily trials of unassisted, spontaneous breathing (T-piece) more substantially reduced the duration of weaning than either SIMV or PSV, the median duration of weaning with each technique were 3, 3, 5 and 4 days, respectively

JAMA 2002; 287: 345–355

N Engl J Med 1995; 332: 345–350

After failed SBT, use of progressively increased time on a T-piece or use of PSV as weaning mode are effective means of liberating patients from the ventilator

Literature does not support the use of SIMV alone as a weaning mode

Eur Respir J 2007; 29: 1033–1056

NON INVESSIVE VENTILATION

In weaning, NIV has been studied for three different indications

First, NIV has been used as an alternative weaning modality for patients who are intolerant of the initial weaning trial

Use of NIV for weaning shortened the total duration of invasive mechanical ventilation and ICU stay, and reduced the rate of nosocomial infection. In two studies a significantly higher survival rate found in the NIV group

Am J Respir Crit Care Med 2003; 168: 70–76

Ann Intern Med 1998; 128: 721–728

Though early extubation can avoid all of the complications of mechanical ventilation, patients who fail SBTs may be at risk for extubation failure

NIV is useful in very selected populations, its use cannot be recommended for all patients failing a SBT.

Ann Intern Med 1998; 128: 721–728

Secondly, use of NIV as a treatment option for patients who have been extubated but developed ARF within 48 h

In two large randomised, multicentre studies NIV was evaluated for treatment of acute respiratory insufficiency occurring in the first 48 h after extubation and was compared with standard oxygen therapy

Neither study showed advantages for the use of NIV

In the study by ESTEBAN et al. NIV group had worse survival compared with the oxygen group.

Overall, the literature does not support the use of NIV as a treatment for extubation failure.

JAMA 2002; 287: 3238–3244N

Engl J Med 2004; 350: 2452–2460

Thirdly, use of NIV as a prophylactic measure after extubation for patients who are at high risk for reintubation but who did not develop ARF

Prophylactic use of NIV used In two studies –

CPAP (5–10 cmH2O) used to prevent reintubation in patients after major abdominal or vascular surgery.

Compared with a control group (post-operative oxygen insufflation), CPAP (mean 7.5 cmH2O) improved oxygenation and reduced the rate of both reintubation and infection.

In both studies there were shorter in hospital stay and a better survival.

Langenbecks Arch Surg 2002; 387: 21–26

JAMA 2005; 293: 589–595

- The evidence for use of NIV in COPD patients and those with hypoxic respiratory failure with concomitant hypercapnic respiratory failure is stronger than in other groups.

- Continuous positive airway pressure-

CPAP has been used for prophylaxis against post-operative extubation failure. SQUADRONE et al. observed that CPAP compared to oxygen supplementation substantially reduced the re-intubation rate

In simple weaning group of patients, CPAP may be an alternative to standard weaning modes but its application in difficult and prolonged weaning group of patients has not been clearly evaluated

There is no of prospective randomised controlled trials to suggest that CPAP is superior to other techniques such as PSV alone or T-tube in weaning from invasive mechanical ventilation

Eur Respir J 2007; 29: 1033–1056

Non-invasive ventilation for weaning, avoiding reintubation after extubation and in the postoperative period: a meta-analysis

A. J. Glossop[1*], N. Shepherd[2], D. C. Bryden[3] and G. H. Mills[3]

[1] NICE Scholar 2010 and Department of Critical Care, Sheffield Teaching Hospitals NHS Foundation Trust, Herries Road, Sheffield S5 7AU, UK
[2] School of Health and Related Research (ScHARR), University of Sheffield, Regent Court, 30 Regent Street, Sheffield S1 4DA, UK

This meta-analysis was performed on the use of NIV in three areas:

weaning

reduction in reintubation rates post-extubation on ICU

reduction in RF after major surgery

Sixteen relevant randomized controlled trials were identified

NIV reduced the ICU length of stay when used for weaning (5.12 days) and post-surgery (0.44 days)

NIV reduced reintubation rates post-surgery [odds ratio (OR) 0.24, 95% confidence interval (CI) 0.12– 0.50]

There is no evidence to suggest NIV improves ICU survival

Increased hospital survival in weaning (OR 0.55, 95% CI 0.31–0.98) and post-surgery (OR 4.54, 0.95% CI 1.35–15.31)

Noninvasive positive-pressure ventilation as a weaning strategy for intubated adults with respiratory failure (Review)

Burns KEA, Meade MO, Premji A, Adhikari NKJ

THE COCHRANE COLLABORATION®

Study population- invasively ventilated adults with respiratory failure of any cause (chronic obstructive pulmonary disease (COPD), non-COPD, postoperative, non-operative) were weaned by means of early extubation followed by immediate application of NPPV or continued IPPV weaning

Primary objective - to determine the noninvasive positive-pressure ventilation (NPPV) weaning strategy reduced all-cause mortality compared with invasive positive-pressure ventilation (IPPV) weaning.

16 trials identified, predominantly of moderate to good quality, involving 994 participants, most with chronic obstructive pulmonary disease

Compared with IPPV weaning, NPPV weaning significantly decreased mortality

The benefits for mortality were significantly greater in trials enrolling exclusively participants with COPD (risk ratio (RR) 0.36, 95% confidence interval (CI) 0.24 to 0.56) versus mixed populations (RR 0.81, 95% CI 0.47 to 1.40)

NPPV significantly reduced-

- weaning failure (RR 0.63, 95% CI 0.42 to 0.96) and
- ventilator-associated pneumonia (RR 0.25, 95% CI 0.15 to 0.43)
- shortened length of stay in an intensive care unit (mean difference (MD) -5.59 days, 95% CI -7.90 to -3.28) and in hospital (MD -6.04 days, 95%CI -9.22 to -2.87)
- reduced tracheostomy (RR 0.19, 95% CI 0.08 to 0.47) and reintubation (RR 0.65, 95% CI 0.44 to 0.97) rates

Ornico *et al. Critical Care* 2013, **17**:R39
http://ccforum.com/content/17/2/R39

CRITICAL CARE

RESEARCH Open Access

Noninvasive ventilation immediately after extubation improves weaning outcome after acute respiratory failure: a randomized controlled trial

Susana R Ornico[1], Suzana M Lobo[1], Helder S Sanches[1], Maristela Deberaldini[1], Luciane T Tófoli[1], Ana M Vidal[1], Guilherme P Schettino[2], Marcelo B Amato[2], Carlos R Carvalho[2] and Carmen S Barbas[2*]

Table 1 Baseline characteristics and diseases that led to acute respiratory failure of the study groups

Variable	NIV (n = 20)	Oxygen mask (n = 18)	P value[a]
Gender (M/F)	14/6	12/6	1.0
Age (years), mean (SD)	50.79 (17.77)	48.88 (22.38)	0.77
Days of MV, mean (SD)	9.85 (8.05)	9.5 (6.06)	0.88
APACHE II, mean (SD)	16.90 (6.81)	15.28 (5.65)	0.43
Pneumonia, number (%)	16 (80)	16 (88.9)	0.66
COPD, number (%)	7 (35)	3 (16.7)	0.28
Abdominal surgery, number (%)	5 (25)	4 (22.2)	1.0
Sepsis, number (%)	4 (20)	2 (11.1)	0.66
Asthma, number (%)	2 (10)	1 (5.5)	1.0
Cardiac failure, number (%)	2 (10)	1 (5.5)	1.0

Noninvasive ventilation, if used immediately after planned extubation, reduced the reintubation rate in mixed ICU patients with respiratory failure requiring mechanical ventilation for more than 72 hours.

Patients weaned by using noninvasive ventilation showed a higher PaO_2, lower $PaCO_2$, respiratory rate and mean blood pressure compared with those using the oxygen mask during the 24- hour period of observation

Patients weaned by using noninvasive ventilation had a significantly lower hospital mortality compared with patients weaned by using an oxygen mask.

Table 2 Outcomes for the study groups

Outcomes	NIV (*n* = 20)	Oxygen mask (*n* = 18)	*P* value[a]
Reintubation, number (%)	1 (5%)	7 (39%)	0.016
Reintubation after excluding COPD, number (%)	0 (0) *n* = 13	5 (33%) *n* = 15	0.044
ICU length of stay, mean (SD)	16.8 (11.6)	18.4 (12.2)	0.681
Hospital mortality, number (%)	0 (0)	4 (22.2%)	0.041

*Significant values with significance level of 0.05. COPD, chronic obstructive pulmonary disease; ICU, intensive care unit; NIV, noninvasive positive-pressure ventilation.

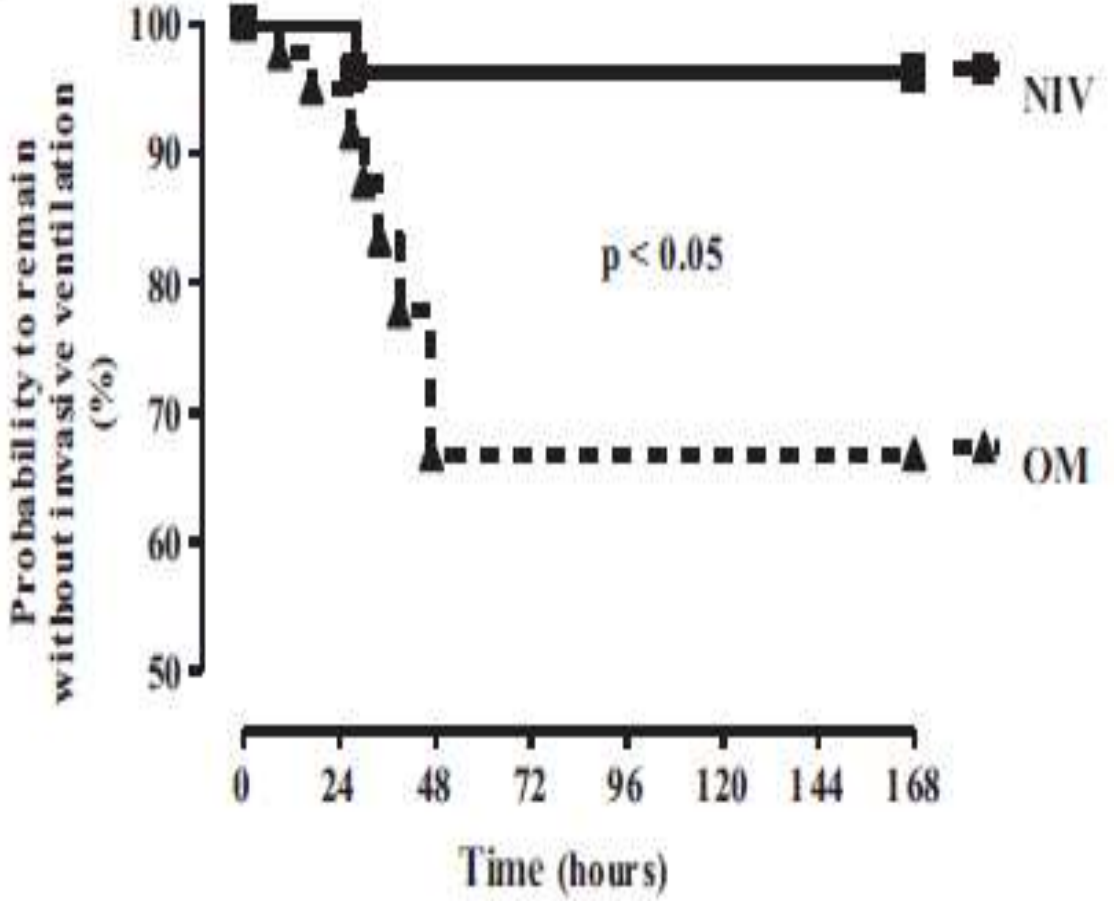


Figure 4 Probability of avoiding reintubation after 168 study hours, by using the Kaplan-Meier curve, with a *P* value obtained with the log-rank test.

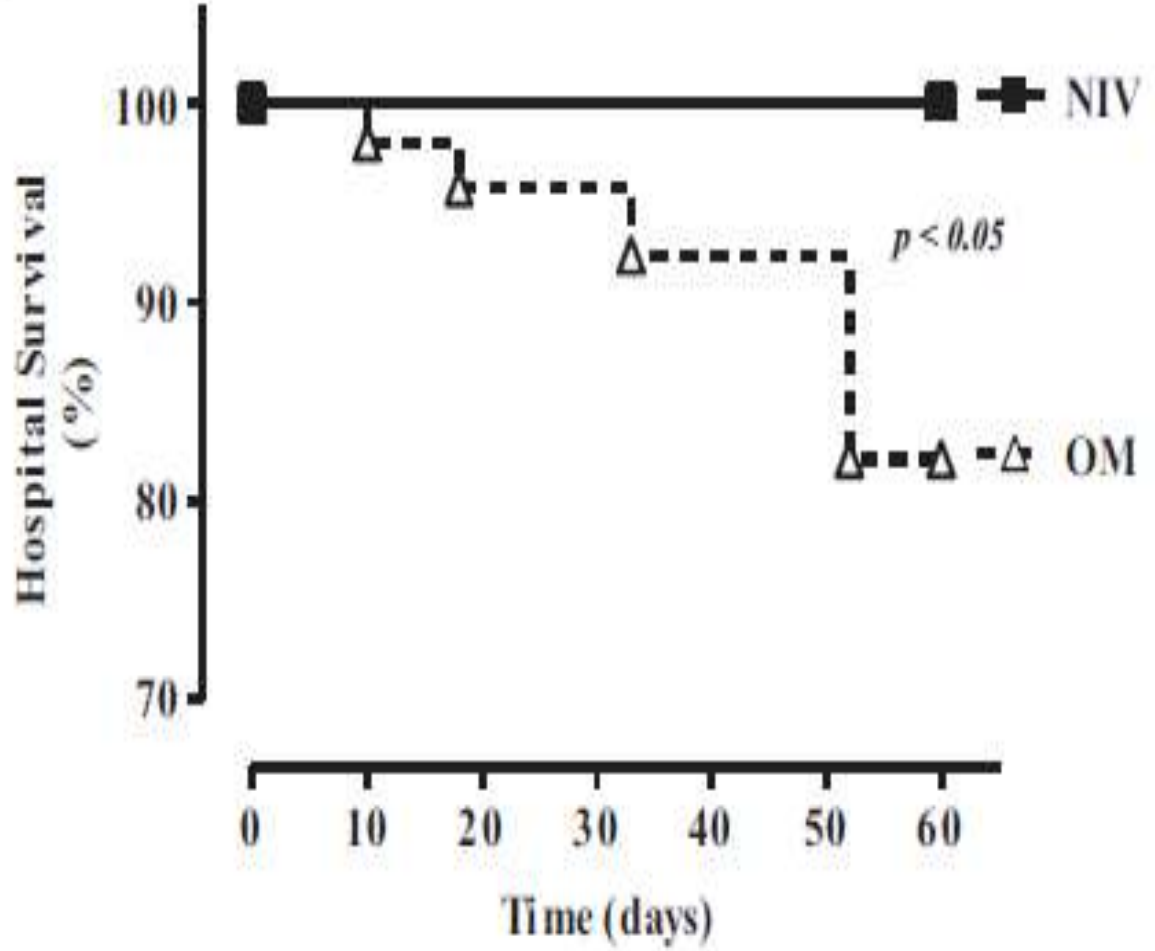


Figure 5 Estimated hospital survival, by using the Kaplan-Meier curve.

- Automatic tube compensation

Use of ATC, a ventilatory method aimed at compensating for the nonlinear pressure drop across the endotracheal tube during spontaneous breathing, is at least as successful as the use of simple T-tube or low-level PS for weaning from mechanical ventilation

Acta Anaesthesiol Scand 2002; 46: 973–979

If an SBT fails because of a particularly narrow endotracheal tube, ATC may be beneficial

For more difficult weaning there is a lack of controlled trials about the use of ATC.

- Proportional assist ventilation-

The physiological response to proportional assist ventilation (PAV) studied in ventilator-dependent patients with COPD

In comparison to PSV and CPAP, there was no substantial difference in oxygenation, pressure time product and other physiological variables. Only when CPAP was combined with PAV a more substantial change in these parameters noted

Am J Respir Crit Care Med 1999; 159: 1510–1517

Intensive Care Med 2003; 29: 949–954.

Application of PAV is difficult and has not been investigated thoroughly in weaning trials.

Eur Respir J 2007; 29: 1033–1056

The New England
Journal of Medicine

Volume 332 FEBRUARY 9, 1995 Number 6

A COMPARISON OF FOUR METHODS OF WEANING PATIENTS FROM MECHANICAL VENTILATION

ANDRÉS ESTEBAN, M.D., PH.D., FERNANDO FRUTOS, M.D., MARTIN J. TOBIN, M.D., INMACULADA ALÍA, M.D., JOSÉ F. SOLSONA, M.D., INMACULADA VALVERDÚ, M.D., RAFAEL FERNÁNDEZ, M.D., MIGUEL A. DE LA CAL, M.D., SALVADOR BENITO, M.D., PH.D., ROSER TOMÁS, M.D., DEMETRIO CARRIEDO, M.D., SANTIAGO MACÍAS, M.D., AND JESÚS BLANCO, M.D., FOR THE SPANISH LUNG FAILURE COLLABORATIVE GROUP*

546 patients who received mechanical ventilation for a mean (±SD) of 7.5± 6.1 days and considered by their physicians to be ready for weaning.

130 patients had respiratory distress during a two-hour trial of spontaneous breathing. These patients were randomly assigned to undergo one of four weaning techniques:

intermittent mandatory ventilation, in which the ventilator rate was initially set at a mean (± SD) of 10.0± 2.2 breaths per minute and then decreased, if possible, at least twice a day, usually by 2 to 4 breaths per minute **(29 patients)**

pressure-support ventilation, in which pressure support was initially set at 18.0± 6.1 cm of water and then reduced, if possible, by 2 to 4 cm of water at least twice a day **(37 patients)**

intermittent trials of spontaneous breathing, conducted two or more times a day if possible **(33 patients)**

once-daily trial of spontaneous breathing (31 patients)

Table 2. The Length of Time from the Initiation of Weaning to Successful Extubation in the Four Groups.

Weaning Technique	Median	First Quartile	Third Quartile
		days	
Intermittent mandatory ventilation	5	3	11
Pressure-support ventilation	4	2	12
Intermittent trials of spontaneous breathing	3	2	6
Once-daily trial of spontaneous breathing	3	1	6

- *Conclusions.* A once-daily trial of spontaneous breathing led to extubation about three times more quickly than intermittent mandatory ventilation and about twice as quickly as pressure-support ventilation. Multiple daily trials of spontaneous breathing were equally successful

A Multicenter Randomized Trial of Computer-driven Protocolized Weaning from Mechanical Ventilation

François Lellouche, Jordi Mancebo, Philippe Jolliet, Jean Roeseler, Fréderique Schortgen, Michel Dojat, Belen Cabello, Lila Bouadma, Pablo Rodriguez, Salvatore Maggiore, Marc Reynaert, Stefan Mersmann, and Laurent Brochard

Réanimation Médicale, AP-HP, Hôpital Henri Mondor, Unité INSERM U 651, Université Paris XII, Créteil; Réanimation Médicale et Infectieuse, AP-HP, Hôpital Bichat, Paris; INSERM/UJF U594, Neuro-imagerie Fonctionelle et Métabolique, LRC CEA 30V, CHU de Grenoble, Grenoble, France; Servei Medicina Intensiva, Hospital Sant Pau, Barcelona, Spain; Soins Intensifs de Médecine, Hôpital Cantonal Universitaire, Geneva, Switzerland; Soins Intensifs–Unité Médico-chirurgicale, Cliniques Universitaires Saint-Luc, Brussels, Belgium; Istituto di Anestesiologia e Rianimazione–Università Cattolica Policlinico A.Gemelli, Rome, Italy; and Dräger Medical AG and Co. KG, Research and Development Critical Care, Lübeck, Germany

This multicenter randomized controlled study compare usual care for weaning with computer-driven weaning

The computerized protocol included an automatic gradual reduction in pressure support, automatic performance of spontaneous breathing trials (SBT), and generation of an incentive message when an SBT was successfully passed

One hundred forty-four patients were enrolled before weaning initiation. They were randomly allocated to computer driven weaning or to physician-controlled weaning according to local guidelines

Primary endpoints-

Weaning duration until successful extubation and

total duration of ventilation

To reach targets, the level of inspiratory assistance in pressure-support ventilation gradually decreased by 2 to 4 cm of water, taking into account the previous breathing-pattern history and automatically tries to reduce the pressure support down to a minimal level

If the patient successfully passes SBT, a message recommending separation from the ventilator is displayed on the screen

FIO2 and PEEP are changed by the physician only

RESULTS-

Weaning duration was reduced in the computer-driven group from a median of 5 to 3 d (p 0.01) and total duration of mechanical ventilation from 12 to 7.5 d (p 0.003).

Reintubation rate did not differ (23 vs. 16%, p0.40).

Computer-driven weaning also decreased median intensive care unit (ICU) stay duration from 15.5 to 12 d (p 0.02) and caused no adverse events.

TABLE 2. COMPARISON OF OUTCOME BETWEEN STUDY GROUPS

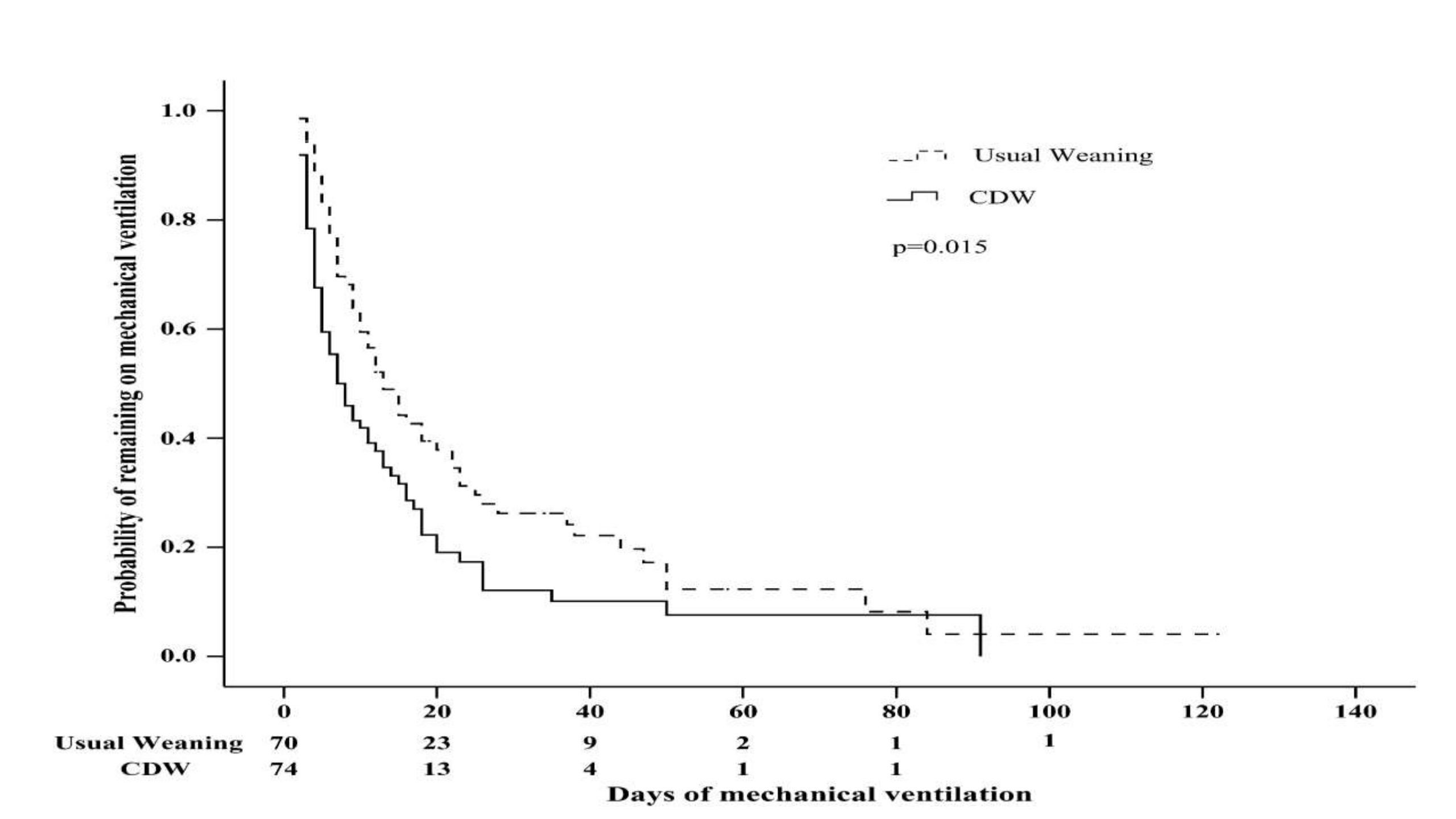
Outcome	CDW Group (*n* = 74)	Usual Weaning Group (*n* = 70)	p Value
Time to first extubation*	2.00 (1.75–6.25)	4.00 (2.00–8.25)	0.02
Duration of mechanical ventilation until first extubation*	6.50 (3.00–12.25)	9.00 (5.75–16.00)	0.03
Time to successful extubation†	3.00 (2.00–8.00)	5.00 (2.00–12.00)	0.01
Total duration of mechanical ventilation†	7.50 (4.00–16.00)	12.00 (7.00–26.00)	0.003
Intensive care length of stay	12.00 (6.00–22.00)	15.50 (9.00–33.00)	0.02
Hospital length of stay	30.00 (17.00–54.75)	35.00 (21.00–60.25)	0.22

Definition of abbreviation: CDW denotes computer-driven weaning.

* The time to first extubation is the time from study inclusion (first positive pressure-support test) to first extubation.

† The time to successful extubation is the time from study inclusion (first positive pressure-support test) to last successful extubation. Total duration of mechanical ventilation is the time from intubation to first or last successful extubation.

Data are expressed as median number of days (25th–75th interquartile range).


Probability of remaining on mechanical ventilation
1.0
0.8
0.6
0.4
0.2
0.0
Usual Weaning
CDW
p=0.015
0
20
40
60
80
100
120
140
Usual Weaning 70 23 9 2 1 1
CDW 74 13 4 1 1
Days of mechanical ventilation

AUTOMATED ADJUSTMENT OF PRESSURE SUPPORT-Neoganesh/Smartcare

NeoGanesh and its commercial version SmartCare constitute an automated, knowledge-based weaning technique

The control algorithm based on clinical reasoning to reproduce the PSV adjustments like a clinician

Control algorithm of the system uses the values of Vt, respiratory frequency and etCO2

Initial MV is automatically determined by the ventilator according to the predicted body weight set by the clinician.

The MV is automatically adjusted

to maintain end-tidal partial pressure of carbon dioxide within acceptable ranges when the patient is not triggering the breath

or

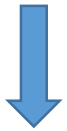
to maintain the patient's RR within acceptable ranges, as defined by the Otis least work of breathing concept, when the patient is triggering the breath-like ASV

The aim is to move the patient toward a zone of respiratory wellbeing in order to start the weaning process

This zone of wellbeing is derived from the patient characteristics (body weight, type of illness, size of the endotracheal tube, type of humidifier). The values are entered by the clinician in the ventilator, and determine the limits of Vt, frequency and etCO2, and the required PSV adjustments.

The automated weaning protocol involves-

automated adaptation of the PSV level



an automated PSV reduction phase

an automated spontaneous breathing test.

Smartcare is able to facilitate the weaning process, reducing resource consumption and shortening the time on mechanical ventilation

Am J Respir Crit Care Med. 2013;187:1203---11

Compared with PSV, Smartcare during a 24-h period improved the Pao2/Fio2 ratio in parallel with more variability in the ventilatory support and more changes in ventilation settings

Anesthesiology, V 119 • No 3

Wean Earlier and Automatically with New Technology (the WEAN Study)

A Multicenter, Pilot Randomized Controlled Trial

Karen E. A. Burns[1,2], Maureen O. Meade[3], Martin R. Lessard[4,5], Lori Hand[6], Qi Zhou[3], Sean P. Keenan[7], and Francois Lellouche[4,8]

Am J Respir Crit Care Med Vol 187, Iss. 11, pp 1203–1211, Jun 1, 2013

Study group- critically ill adults requiring more than 24 hours of mechanical ventilation and at least partial reversal of the condition precipitating respiratory failure at nine Canadian intensive care units

Randomization- patients who tolerated at least 30 minutes of pressure support and either failed or were not yet ready to undergo a spontaneous breathing trial were randomized to automated or protocolized weaning.

- Both groups-

1. used pressure support, included spontaneous breathing trials

2. Had common PEEP–FIO2 chart, sedation protocol, and criteria for extubation, reintubation, and noninvasive ventilation

Recruitement- 92 patients (49 automated, 43 protocolized) over 26 months

Result-Automated weaning patients –

significantly shorter median times to first successful spontaneous breathing trial (1.0 vs. 4.0 d; $P < 0.0001$)

extubation (3.0 vs. 4.0 d; $P < 0.02$)

and successful extubation (4.0 vs. 5.0 d; $P < 0.01$)

underwent fewer tracheostomies and episodes of protracted ventilation.

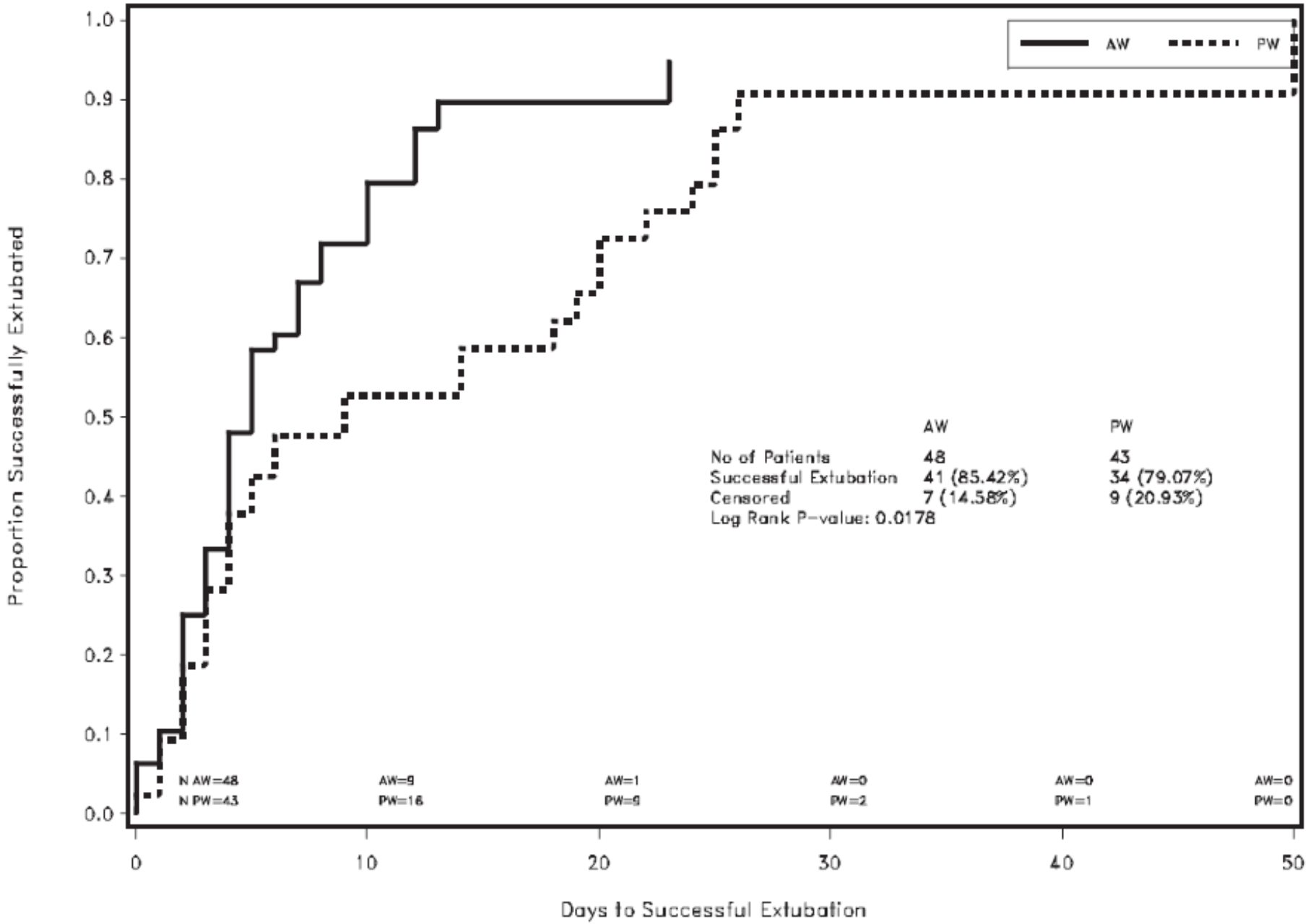


Figure 2. Time to successfu extubation for the two treatmer groups (Kaplan-Meier curves) AW = automated weaning PW = protocolized weaning.

Rose et al. Critical Care (2015) 19:48
DOI 10.1186/s13054-015-0755-6

CRITICAL CARE

RESEARCH Open Access

Automated versus non-automated weaning for reducing the duration of mechanical ventilation for critically ill adults and children: a cochrane systematic review and meta-analysis

Louise Rose[1,2,3,4,5*], Marcus J Schultz[6], Chris R Cardwell[7], Philippe Jouvet[8], Danny F McAuley[9] and Bronagh Blackwood[10]

- Weaning duration- Pooled data from 16 trials indicated automated systems reduced weaning duration equivalent to a 30% (95% CI 13% to 45%)
- Subgroup analyses according to ICU population demonstrated reduced weaning duration in trials of mixed/medical ICU patients - 42% (10% to 63%) reduction in geometric mean.
- No evidence of effect was found in trials including only surgical ICU patients.
- Smartcare/PS™ reduced weaning duration 28% (7% to 49%) whereas in ASV 3% reduction in geometric mean
- There was no subgroup difference according to the weaning method used in the control arm with broadly overlapping CIs.

Automated systems reduced the time to first extubation, ventilation duration, ICU LOS, tracheostomy and prolonged ventilation

There was no strong evidence of an effect on mortality, reintubation, self-extubation, postextubation or hospital LOS.

- ADAPTIVE SUPPORT VENTILATION

- ASV is a closed-loop control mode that may switch automatically from a PCV-like behavior to an SIMV-like or PSV like behavior, according to the patient status
-
- Unlike for PCV, SIMV, or PSV, ASV always maintains control of ventilation volume and it guarantees— a minimum minute ventilation set by the user, — an effective tidal volume, well above the theoretical dead space of the patient, and — a minimal breath rate. ASV can execute the following commands-

- Respir Care 2012;57(10):1635–1648.

TABLE I.—*Function of ASV explained as a command to a hypothetical agent within a ventilator.*[1]

— Maintain at least a pre-set minute ventilation
— Take spontaneous breathing into account
— Prevent tachypnea
— Prevent AutoPEEP
— Prevent excessive dead space ventilation
— Fully ventilate in apnea or low drive
— Give control to patient in case brearhing activity is OK, and do all this without exceeding a plateau pressure of 10 mbar below the upper pressure limit

In most studies, it was used only in the weaning phase, and patients were ventilated with conventional modes until weaning

ASV is an adaptive pressure controlled ventilation in passive patients and switches to an adaptive pressure support ventilation (PSV) in spontaneously breathing patients

Respir Care 2012;57(10):1635–1648.

ASV provides a mandatary minute ventilation.

Ventilator measures dynamic compliance and expiratory time constant to adjust the mechanical tidal volume and frequency for a target minute ventilation.

The optimal tidal volume is calculated by dividing minute ventilation by optimal frequency in terms of lowest work of breathing.

ASV use Oti's equation to calculate optimal frequency that correspond to lowest work of breathing.

With ASV mode the therapist input patient's body wt and desired percent minute volume.

Body wt is used to calculate the dead space volume and to calculate alveolar volume.

- Respir Care 2012;57(10):1635–1648.

- For estimated minute ventilation requirement of a patient, ventilator use predetermined setting of 100ml/kg/min for adults and 200ml/kg/min for children.
- Therapist may select percent minute volume ranging from 20% to 200% of the predetermined adult or child setting. If 160% is selected for an adult, min ventilation delivered by ventilator will be 160ml/kg/min.

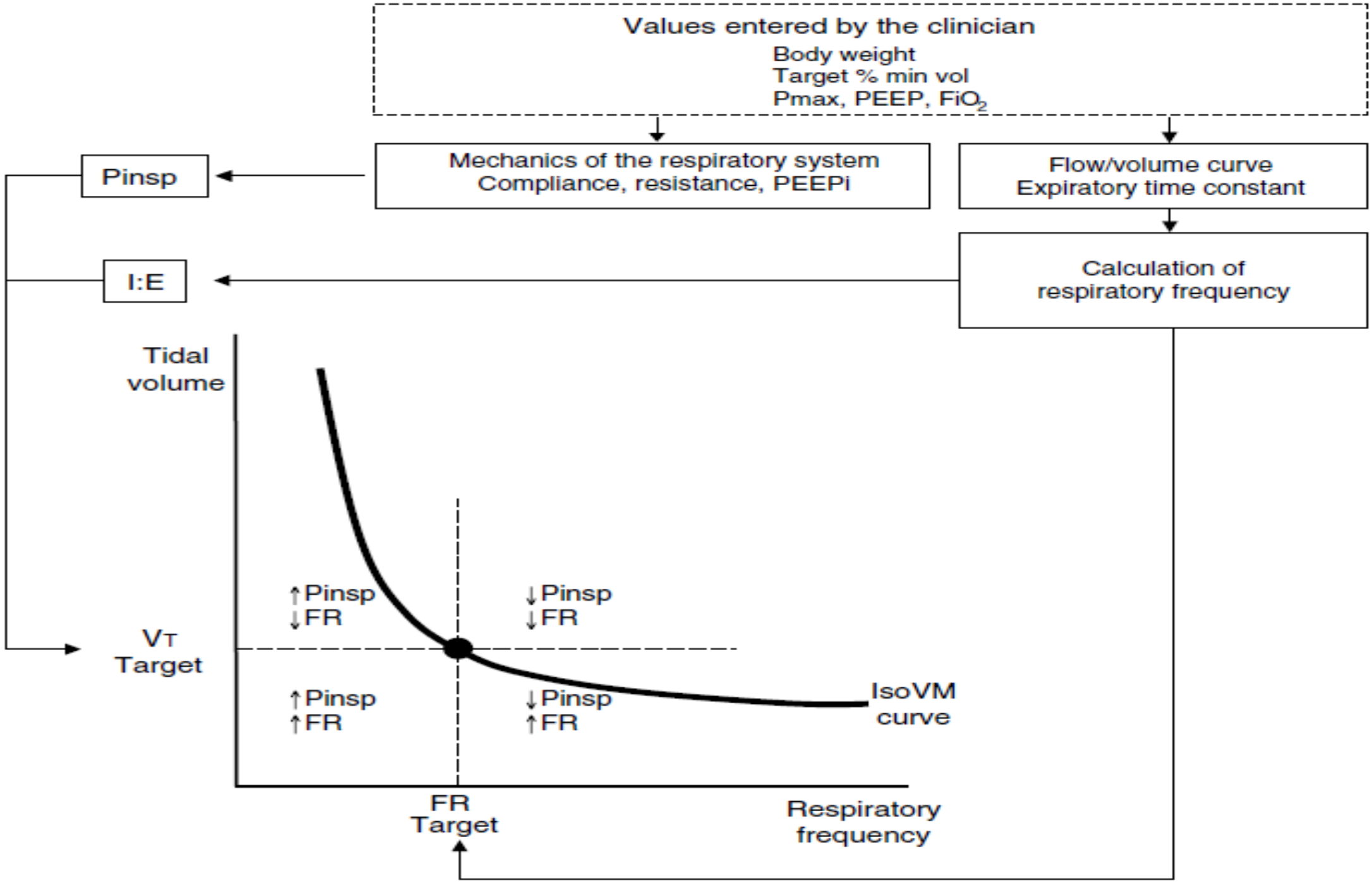
- Once the target min ventilation is set, ventilator use test breath to measure systemic compliance, airway resistance and any intrinsic PEEP.

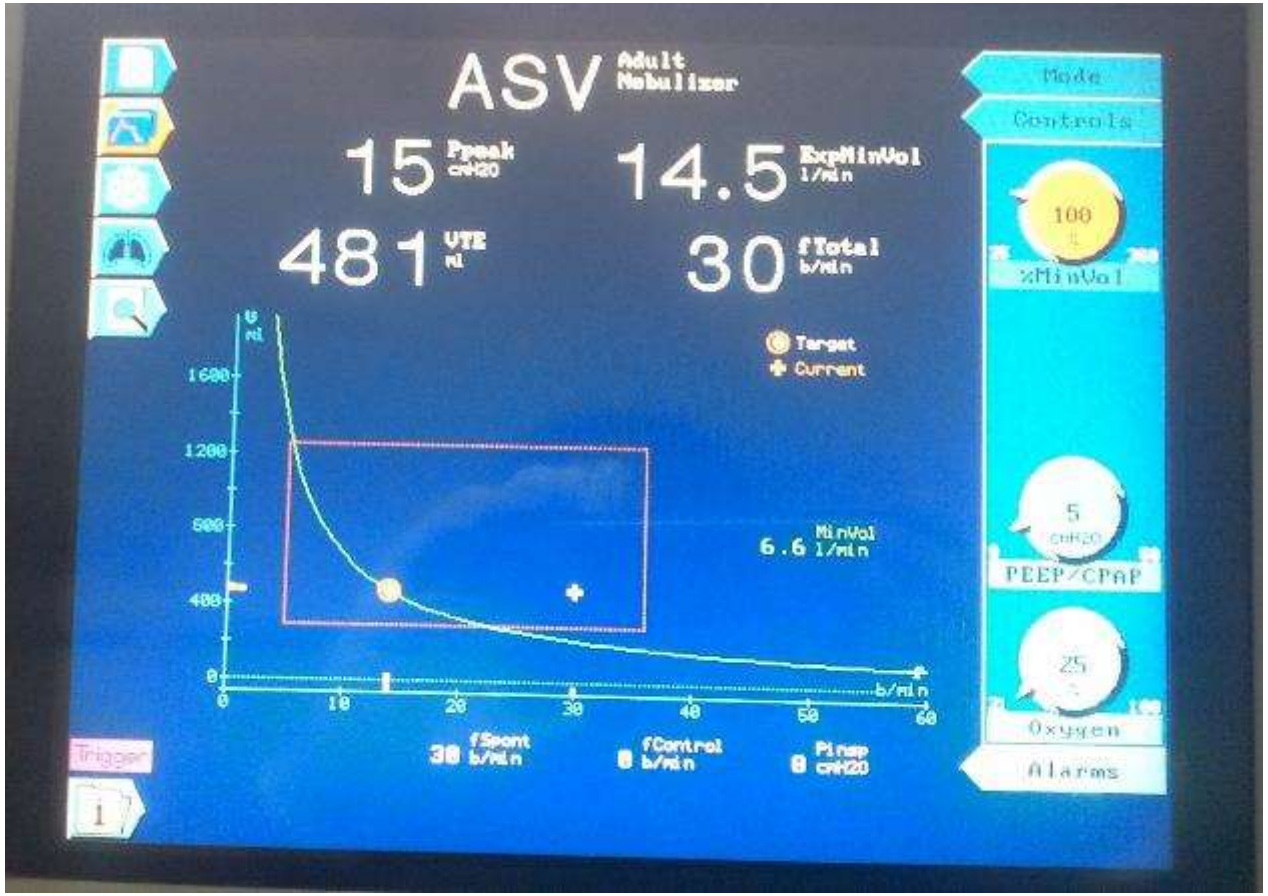
- Respir Care 2012;57(10):1635–1648.

If there is no spontaneous triggering effort , ventilator determines and provides mandatory frequency, tidal volume and high pressure limit needed to deliver preselected minute volume.

When patient begins to trigger the ventilator, number of mandatory breath decreases and pressure support level increases until a calculated tidal volume is able to provide an adequate alveolar volume

Respir Care 2012;57(10):1635–1648


Values entered by the clinician
Body weight
Target % min vol
Pmax, PEEP, FiO2
Mechanics of the respiratory system
Compliance, resistance, PEEPi
Flow/volume curve
Expiratory time constant
Pinsp
I:E
Calculation of
respiratory frequency
Tidal
volume
↑Pinsp
↓FR
↓Pinsp
↓FR
VT
Target
↑Pinsp
↑FR
↓Pinsp
↑FR
IsoVM
curve
FR
Target
Respiratory
frequency


ASV
Adult
Nebulizer
15
Ppeak
cmH2O
14.5
ExpMinVol
l/min
481
VTE
ml
30
fTotal
b/min
Target
Current
MinVol
6.6 l/min
fSpont
30 b/min
fControl
0 b/min
Pinsp
0 cmH2O
Trigger
Mode
Controls
100
%MinVol
5
cmH2O
PEEP/CPAP
25
Oxygen
Alarms
b/min

Eur Respir J 2011; 38: 774–780
DOI: 10.1183/09031936.00081510

Adaptive support ventilation for faster weaning in COPD: a randomised controlled trial

C. Kirakli*, I. Ozdemir#, Z.Z. Ucar*, P. Cimen*, S. Kepil# and S.A. Ozkan#

	INCLUSION CRITERIA	Aim of study	randomization	results	conclusion
	From among 435 COPD patients admitted to the intensive care unit (ICU) during a 20-month period, 97 were enrolled. Patients were assigned at random to either ASV or PSV as a weaning mode.	Primary outcome-weaning duration Secondary outcome-weaning success rates, respiratory parameters at the end of the weaning period, duration of mechanical ventilation and length of stay (LOS) in the ICU	97 intubated COPD patients who were ready for weaning 49 randomized to ASV group and 47 randomized to PSV group	Compared with PSV, ASV provided shorter weaning times (median 24 h versus 72 h p<.041) with similar weaning success rates (35 out of 49 for ASV and 33 out of 48 for PSV). Length of stay in the ICU - shorter with ASV but not statistically significant.	ASV may be used in the weaning of COPD patients with the advantage of shorter weaning times.

[Original Research **Critical Care**]

CHEST

A Randomized Controlled Trial Comparing the Ventilation Duration Between Adaptive Support Ventilation and Pressure Assist/Control Ventilation in Medical Patients in the ICU

Cenk Kirakli, MD; Ilknur Naz, PT, MS; Ozlem Ediboglu, MD; Dursun Tatar, MD; Ahmet Budak, MD; and Emel Tellioglu, MD

	Study population	outcome	randomization	RESULTS	CONCLUSION		
Cenk Kirakli et al CHEST 2015; 147(6): 1503 - 1509	Adult medical patients intubated and mechanically ventilated for . 24 h in a medical ICU	Primary outcome- total MV duration. Secondary outcomes- weaning duration, number of manual settings of the ventilator, and weaning success rates	ASV(N=114) or PSV(N=115)	Median MV duration until weaning, weaning duration, and total MV duration were significantly shorter in the ASV number of patients extubated successfully on the first attempt was significantly higher in the ASV group (*P* 5 .001)	In medical patients in the ICU, ASV may shorten the duration of weaning and total MV duration with a fewer number of manual ventilator settings		

Adaptive Support Ventilation Versus Synchronized Intermittent Mandatory Ventilation With Pressure Support in Weaning Patients After Orthotopic Liver Transplantation

P. Celli[a,*], E. Privato[a], S. Ianni[a], C. Babetto[a], C. D'Arena[a], N. Guglielmo[b], F. Maldarelli[a], G. Paglialunga[a], M. Rossi[b], P.B. Berloco[b], F. Ruberto[a], and F. Pugliese[a]

[a]Dipartimento di Anestesia e Rianimazione, UOD Anestesia e Terapia Intensiva Trapianti d'Organo, Policlinico Umberto I, "Sapienza," Rome, Italy; and [b]Dipartimento di Chirurgia Generale e Trapianti d'Organo "Paride Stefanini," Policlinico Umberto I, "Sapienza," Rome, Italy

	AIM OF STUDY		RANDOMIZATION	RESULTS	CONCLUSION
P. Cellia et al	to compare the adaptive support ventilation (ASV) mode with the standard mode of weaning in intensive care unit, synchronized intermittent mandatory ventilation with pressure support (P-SIMV), in patients who received orthotopic liver transplantation		Eligible patients were assigned to either ASV or P-SIMV group.	The average length of intubation was significantly shorter in the ASV group than in the P-SIMV group (90 13 vs 153 22 minutes, P ¼ .05). The total modifications to the ventilator settings were significantly larger in the P-SIMV group (1.5 1 vs 6 2; P ¼ .003	ASV is superior in terms of weaning times, and it simplifies respiratory management

NAVA

- NAVA is an assist mode of MV that delivers a pressure proportional to the integral of the electrical activity of the diaphragm (EAdi)

and

- Also proportional to the neural output of the patient's central respiratory command.

Nat Med 1999, 5:1433-1436

With NAVA, the ventilator is triggered and cycled-off based on the EAdi value, which directly reflects the activity of the neural respiratory command

The inspiratory airway pressure applied by the ventilator is determined by the following equation:

Peak pressure (cmH_2O)=NAVA level x (Edi peak–Edi min)+PEEP

Nat Med 1999, 5:1433-1436

The Edi peak represents maximal electrical activity of the diaphragm for a particular breath (in µV)

The Edi min represents the electrical activity of the diaphragm between inspiratory efforts (in µV).

No literature provides evidence that NAVA improves survival, length of ICU stay or time spent on the ventilator

Compared to other ventilatory modes, ventilator support in NAVA more closely resembles normal respiratory physiology

Patient-ventilator synchrony improves in NAVA compared to Pressure Support ventilation

Patients at risk for asynchrony with the ventilator (i.e. intrinsic PEEP, respiratory muscle weakness) benefit from NAVA

Improved patient-ventilator synchrony improve quality of sleep

Terzi et al. Critical Care 2012, **16**:225

Contraindications for NAVA ventilation:

Known contraindications for naso-/orogastric feeding tube (including recent upper airway surgery, esophageal surgery, recent esophageal bleeding, skull base fracture)

Known phrenic nerve lesions

Congenital myopathy (relative contraindication)

MRI scanning: the Edi Catheter is not approved for use in MRI environments

- Nasal insertion of Edi Catheter-

Appropriate catheter size (usually 16 Fr, 125 cm) is chosen

Insertion length calculated according to formula

Catheter is rinsed with water. This activates the lubricant on the catheter. Use of silicon spray or other lubricants is avoided which result in catheter malfunctioning

Edi catheter inserted according to protocol “insertion nasogastric feeding tube”

- Edi Module tested by connecting one end of the Edi Cable to the Edi Module and the other end to the test plug.
- Wait until the message “Test passed” appears on the ventilator screen.
- Edi Cable connected to Edi Catheter.
- “Neural access” menu on the ventilator is opened
- “Edi Catheter positioning” selected

- Catheter position checked: usually there are P waves and QRS complexes in the upper leads. In the lower leads, the P waves disappear and the amplitude of the QRS complexes decreases

- Middle two ECG leads are highlighted in blue during an inspiratory effort. If the upper leads are highlighted in blue during inspiration, withdraw catheter a short distance 1 to 2 cm. If the lower leads are highlighted move the catheter downwards
- A low or absent Edi may be due to any of the following:

hyperventilation

sedation

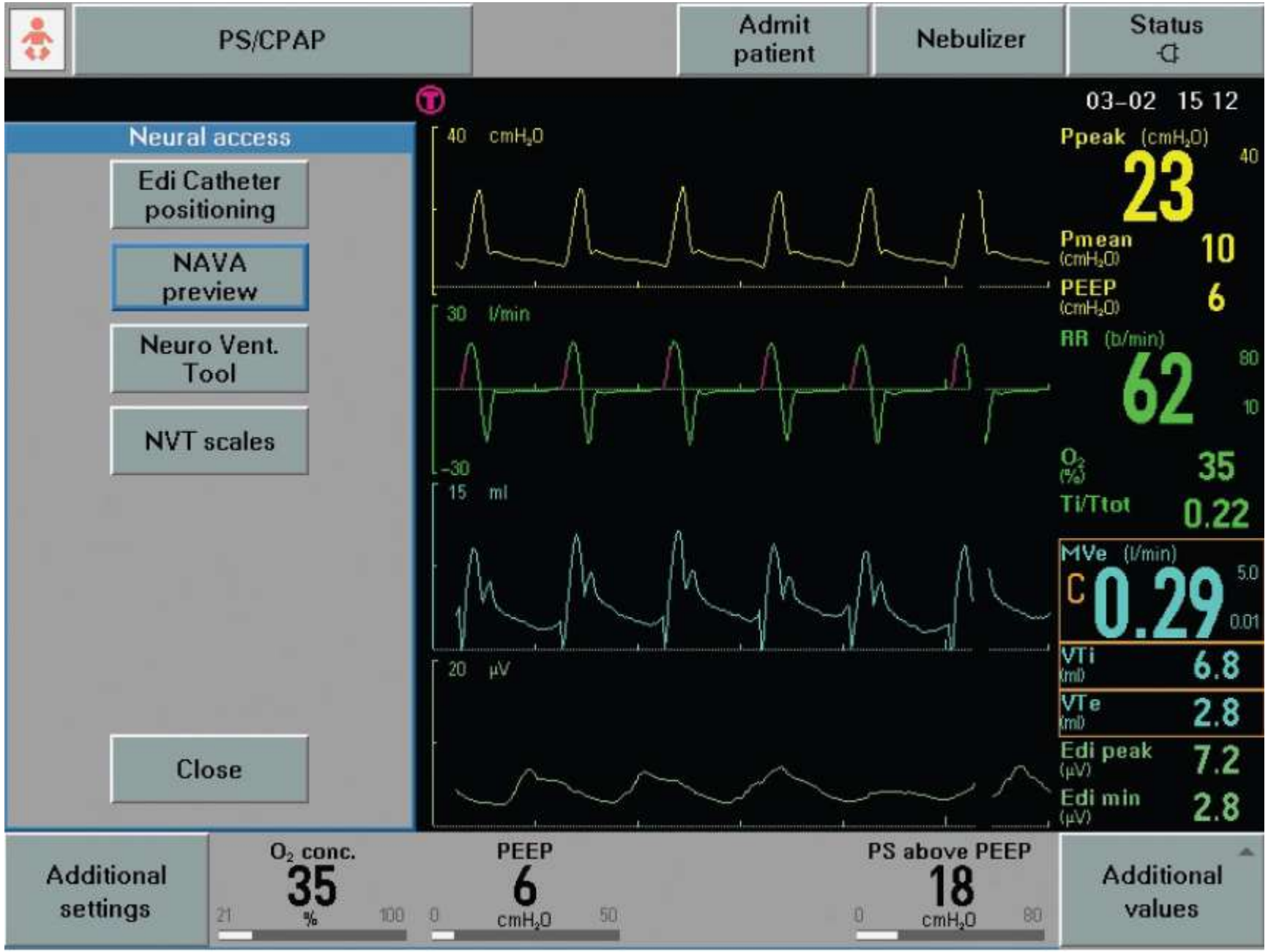
muscle relaxants

neural disorders

- Calculation of the insertion distance (Y) for the Edi Catheter- This will depend on whether the Edi Catheter is inserted orally or nasally, as well as on the size of the Edi Catheter
- **Insertion distance Y for nasal insertion**
- **Fr/cm Calculation of Y**
- 8 Fr 100 cm NEX cm x 0.9 + 8 = Y cm
- 6 Fr 50 cm NEX cm x 0.9 + 3.5 = Y cm
- 6 Fr 49 cm NEX cm x 0.9 + 2.5 = Y cm
- **Insertion distance Y for oral insertion**
- **Fr/cm Calculation of Y**
- 8 Fr 100 cm NEX cm x 0.8 + 8 = Y cm
- 6 Fr 50 cm NEX cm x 0.8 + 3.5 = Y cm
- 6 Fr 49 cm NEX cm x 0.8 + 2.5 = Y cm

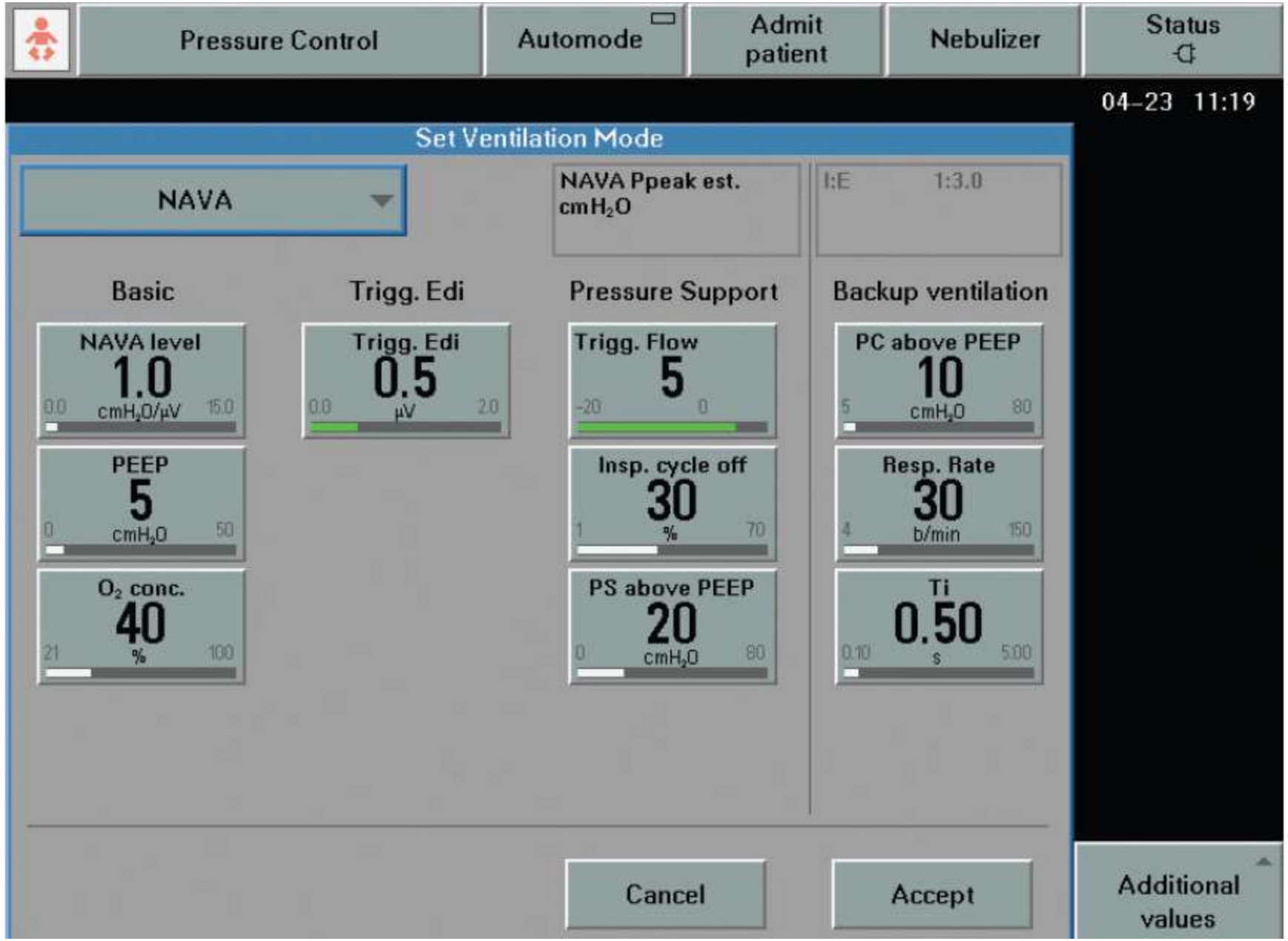
Setting initial NAVA level -The initial NAVA level selected based on the level of support provided using conventional ventilator modes (Pressure Support or Pressure Control):

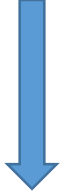
- Open “Neural access”
- Select “NAVA preview” (accessible in all ventilatory modes except in NAVA)
- Two pressure curves appear in the upper window: a yellow one, that represents the actual pressure delivery, and a gray one that provides an estimation of the pressure delivered (based on actual Edi and NAVA level) if the patient were switched to NAVA at this time.


PS/CPAP
Admit patient
Nebulizer
Status
03-02 15 12
Neural access
Edi Catheter positioning
NAVA preview
Neuro Vent. Tool
NVT scales
Close
40 cmH2O
30 l/min
-30
15 ml
20 µV
Ppeak (cmH2O)
40
23
Pmean (cmH2O) 10
PEEP (cmH2O) 6
RR (b/min)
80
62
10
O2 (%) 35
Ti/Ttot 0.22
MVe (l/min)
C 0.29
5.0
0.01
VTi (ml) 6.8
VTe (ml) 2.8
Edi peak (µV) 7.2
Edi min (µV) 2.8
Additional settings
O2 conc. 35 % 21 100
PEEP 6 cmH2O 0 50
PS above PEEP 18 cmH2O 0 80
Additional values


PS/CPAP
Admit patient
Nebulizer
Status
03-02 15 13
NAVA preview
NAVA press. estimate
NAVA level
1.7
0.0
cmH2O/µV
15.0
Close
40 cmH2O Pest
30 l/min
-30
15 ml
20 µV
Ppeak (cmH2O)
24
40
Pmean (cmH2O)
10
PEEP (cmH2O)
6
RR (b/min)
62
80
10
O2 (%)
30
Ti/Ttot
0.22
MVe (l/min)
C 0.31
5.0
0.01
VTi (ml)
8.7
VTe (ml)
4.5
Edi peak (µV)
6.0
Edi min (µV)
3.0
Additional settings
O2 conc.
35
%
21
100
PEEP
6
cmH2O
0
50
PS above PEEP
18
cmH2O
0
80
Additional values

- Adapt the NAVA level so that the area under the estimated pressure curve (gray) resembles the area under the actual pressure curve (yellow). If satisfactory, press “Accept”.
- Press “NAVA” in “Select ventilation mode”
- The NAVA level that appears is based on the level selected in the preview window. Set adequate values for PEEP, FiO2, levels for Pressure Support and backup ventilation in this window.
- Reduce actual NAVA level by 0.2 µV/cmH2O and after 20 sec evaluate whether or not the patient is still comfortable. If so, a further reduction in NAVA level can be made.


Pressure Control
Automode
Admit patient
Nebulizer
Status
04–23 11:19
Set Ventilation Mode
NAVA
NAVA Ppeak est. cmH2O
I:E 1:3.0
Basic
Trigg. Edi
Pressure Support
Backup ventilation
NAVA level 1.0 cmH2O/µV 0.0 15.0
Trigg. Edi 0.5 µV 0.0 2.0
Trigg. Flow 5 -20 0
PC above PEEP 10 cmH2O 5 80
PEEP 5 cmH2O 0 50
Insp. cycle off 30 % 1 70
Resp. Rate 30 b/min 4 150
O2 conc. 40 % 21 100
PS above PEEP 20 cmH2O 0 80
Ti 0.50 s 0.10 5.00
Cancel
Accept
Additional values



- If the patient becomes uncomfortable, return to the previous NAVA level. This should be repeated twice daily.

- The usual NAVA level is between 0.5 and 3.0 µV/cmH2O.

- In ARDS patients, the tidal volume should be taken into account (generally below 6 ml/kg predicted body weight).

Clinical protocol: NAVA

- MANAGEMENT OF NAVA LEVEL

- Brander and colleagues tried to find the best NAVA level using breathing pattern analysis during a titration procedure . Titration consisted of starting at a minimal assist level of around 3 cmH2O and then increasing the NAVA level every 3 minutes in steps of 1 cmH2O per arbitrary unit (the amount of microvolts recorded from the EAdi signal)

The response in terms of VT and Paw was biphasic

During the first phase, VT and Paw increase while the esophageal pressure–time product (that is, inspiratory muscle effort) and Eadi decrease

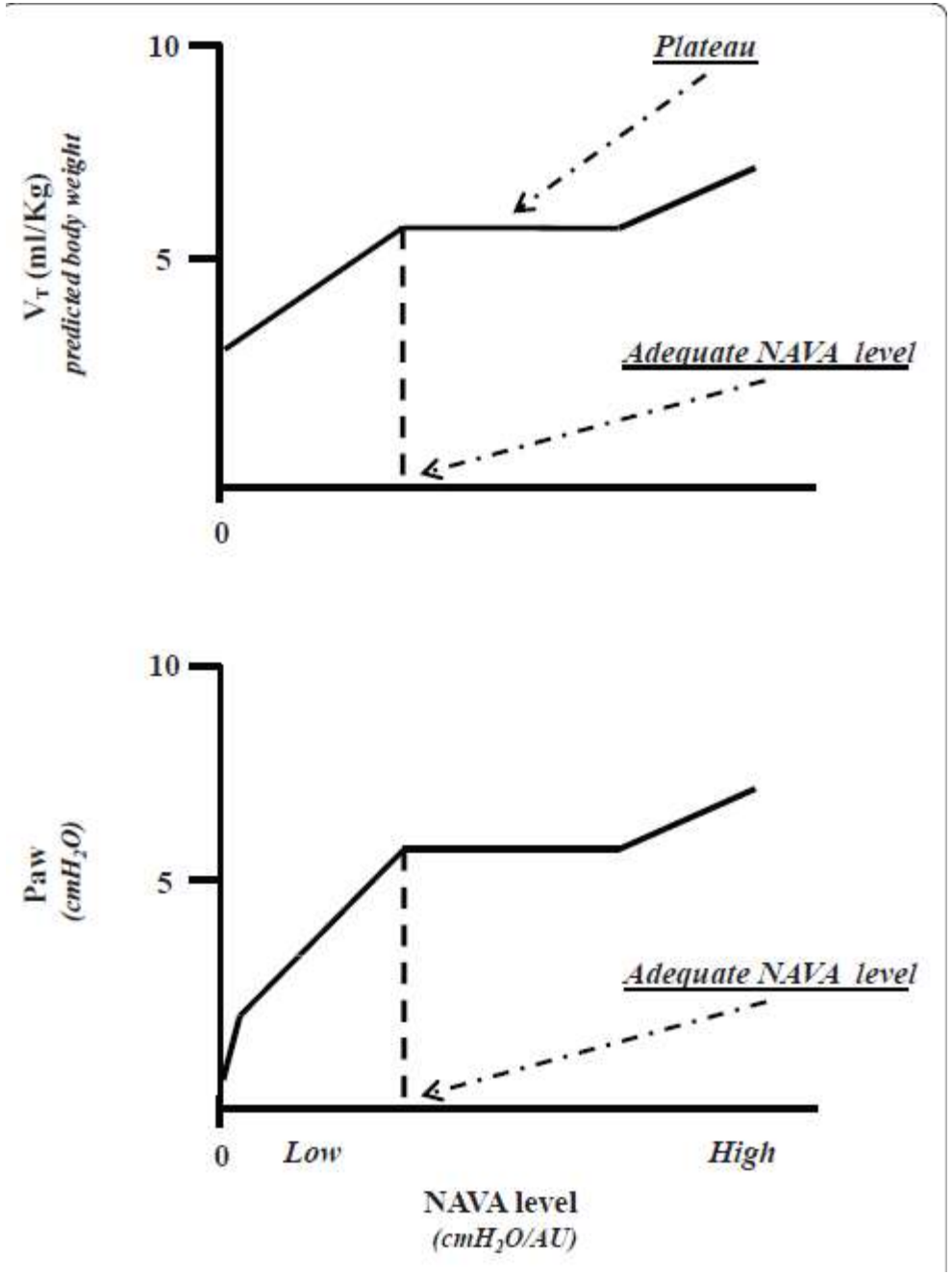
Further increases in the NAVA level (second phase) do not significantly change Paw or VT but continue to decrease the esophageal pressure–time product and EAdi.

- Chest 2009, 135:695-703

The first phase may thus indicate an insufficient NAVA level to supplement the patient's weak breathing effort, while the beginning of the second phase correspond to the minimal assist level that satisfies the patient's respiratory demand.

The optimal (or adequate) NAVA level is indicated by the inflection point of the airway pressure trend graph during a stepwise increase in the NAVA level

Chest 2009, 135:695-703


10
5
0
Plateau
Adequate NAVA level
V_T (ml/Kg)
predicted body weight
10
5
0
Low
High
Adequate NAVA level
Paw
(cmH_2O)
NAVA level
(cmH_2O/AU)

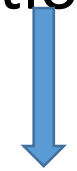
- Instead of stepwise titration, Roze and colleagues tried to find the best NAVA level using an EAdi target of 60% of the highest EAdi value recorded during spontaneous breathing . This measurement is reassessed daily using a spontaneous breathing trial with a pressure support level of 7 cmH2O and no PEEP.
- The 60% of the highest EAdi value threshold is based on a muscular rehabilitation protocol developed using data on diaphragmatic electromyogram activation during exercise

Intensive Care Med 2011, 37:1087-1094

Weaning patients from NAVA –

Patients on NAVA may be weaned using a similar strategy to that used for weaning patients on Pressure Support ventilation-

Gradual reduction in NAVA level



Consider spontaneous breathing trial daily when Ppeak – PEEP<10 cm of water

The first sign that it is possible to wean the patient is a decline in the Edi signal with maintained tidal volume.

If an increase in sedation is not the cause of the decline in the Edi signal then the decrease provides confirmation of an improvement in neuromuscular coupling and mechanical efficiency of diaphragm and weaning process starts automatically.

Terzi et al. Critical Care 2012, **16**:225

When the patient is stable and the tidal volume is unchanged while the Edi signal is declining or unchanged, reduce the NAVA level in steps of 0.1-0.2 cmH2O/µV.

If VT is reduced and the Edi signal increases disproportionally, go back to the previous setting. This indicate that patient is not yet ready to be weaned

Allow the patient to rest on the previous setting and try again later

Terzi et al. Critical Care 2012, **16**:225

High respiratory rate:

In NAVA, the respiratory rate usually higher compared to Pressure Support

Reasons - absence of wasted efforts in NAVA

High respiratory rate, and a chaotic breathing pattern, are characteristic of NAVA. This should not be regarded as agitation

Clinical protocol: NAVA

- Triggering in NAVA mode:

In NAVA, the ventilator provides support on a “first- come-first-served” basis. If inspiratory flow is sensed before a rise in the Edi signal, the breath will be flow-triggered but the breath delivered will remain proportional to the Edi signal

Even if all breaths are flow-triggered while in NAVA mode the ventilatory pattern will still be different from that in Pressure Support ventilation

Reasons for flow triggering of breaths while in NAVA –

1. early activation of accessory respiratory muscles and
2. limitations in Edi signal analysis by software.

- NAVA versus NAVA (PS) –

For safety reasons, the machine switches automatically to Pressure Support under certain circumstances, including:

Catheter disconnection

Too much ECG interference with the Edi signal

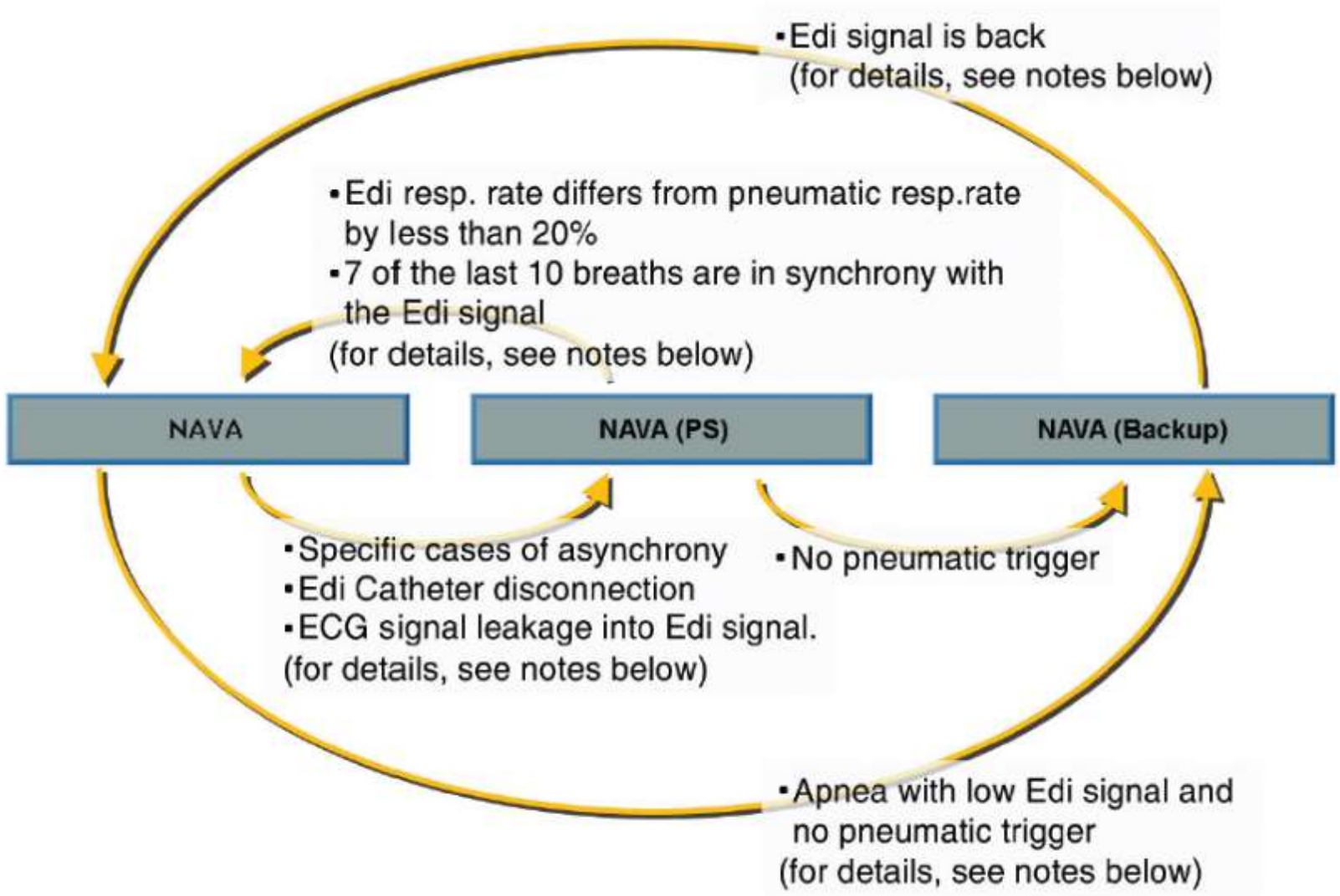
Major discrepancies between flow/pressure and Edi signals

If the ventilator subsequently detects an adequate Edi signal, it will switch back to NAVA automatically

If no patient efforts are detected for a certain time period (the apnea time, default 20 seconds), the ventilator automatically switches to Pressure Control ventilation as the backup mode

Switching between NAVA, NAVA (PS) and NAVA (Backup)

NAVA – NAVA (PS) – NAVA (Backup)



NAVA, in contrast to PSV, decreases the risk of over assistance when the assist level was increased gradually

NAVA improves patient– ventilator synchrony compared to PSV regardless of the underlying diagnosis.

Crit Care Med 2010, 38:518-526

Crit Care Med 2010, 38:1830-1837

NAVA compared with PSV improve the partial pressure of oxygen in arterial blood independent of changes in the partial pressure of carbon dioxide in arterial blood (PaCO2)

Continuous spontaneous inspiratory activity during NAVA improves V/Q mismatch and improved gas exchange

Crit Care Med 2008, 36:818-827

Crit Care Med 2010, 38:1830-1837

- **Noninvasive ventilation and NAVA**

In NIV occurrence of leaks may greatly affect patient–ventilator interactions complicating optimal ventilator settings.

In study by Vignaux and colleagues, more than 40% of patients experienced various types of asynchrony during conventional NIV and the asynchrony rate correlated with the level of leakage.

Intensive Care Med 2009,35:840-846.

With NAVA, assistance is delivered based on neural triggering, which is not affected by leakage. NAVA can diminish asynchrony events, thereby improving the tolerance of NIV.

Intensive Care Med 2011, 37:1943-1950

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.**

This study aimed to compare the ventilatory and gas exchange effects between NAVA and pressure support ventilation (PSV) during the weaning phase of critically ill patients requiring mechanical ventilation after surgery

Method-Fifteen patients underwent abdominal surgery, were enrolled.

They were ventilated with PSV and NAVA for 24 h each in a randomized crossover order

The ventilatory parameters and gas exchange effects produced by the two ventilation modes- compared

Results: The PaO2/FIO2 (mean ±SD) ratio in NAVA significantly higher than with PSV (264±71 *vs.* 230±75 mmHg, *P*0.05). PaCO2 did not differ significantly between the two modes

Variability of insufflation airway pressure, tidal volume, and minute ventilation- significantly higher with NAVA than with PSV

Electrical activity of the diaphragm variability significantly lower with NAVA than with PSV

Conclusions: Compared with PSV, respiratory parameter variability was greater with NAVA leading to the significant improvement in patient oxygenation

Weaning from mechanical ventilation is associated with the presence of asynchronies between the patient and the ventilator.

AI greater than 10 % is associated with an increase in the duration of mechanical ventilation and an increase in use of tracheotomy for ventilator weaning.

Intensive Care Med. 2006;32:1515–22

NAVA can be helpful in patients with difficult weaning by reducing the number of asynchronies in patients with a high AI

RESEARCH ARTICLE Open Access

Patient-ventilator synchrony in Neurally Adjusted Ventilatory Assist (NAVA) and Pressure Support Ventilation (PSV): a prospective observational study

Hodane Yonis, Laure Crognier, Jean-Marie Conil, Isabelle Serres, Antoine Rouget, Marie Virtos, Pierre Cougot, Vincent Minville, Olivier Fourcade and Bernard Georges*

Methods: Thirty patients were included in the study. Patients were successively ventilated for 23 h in NAVA or in PSV, and then they were ventilated for another 23 h in the other mode.

Results:

The median level of support was 12.5 cmH2O (4–20 cmH2O) in PSV and 0.8 cmH2O/μvolts (0.2–3 cmH2O/μvolts) NAVA.

The total number of asynchronies per minute in NAVA was lower than that in PSV (0.46 vs 1, $p < 0.001$).

The asynchrony index was also reduced in NAVA compared with PSV (1.73 vs 3.36, $p < 0.001$). In NAVA, the percentage of ineffective efforts (0.77 vs 0.94, $p = 0.036$) and the percentage of auto-triggering were lower compared with PSV (0.19 vs 0.71, $p=0.038$).

The decrease in the number of asynchronies in NAVA is due to reduced ineffective efforts and auto-triggering

- **Neurally adjusted ventilatory assist in children and Infants**

MV in children and in low-birth-weight infants is more difficult to apply than in adults

Infants take a very small tidal volume, have a rapid respiratory rate, limited chest wall musculature & variable and fluctuating lung compliance.

Most neonatal units use uncuffed tracheal tubes for fears of pressure necrosis and air leak is always present, making reliable measurements and triggering problematic.

Terzi et al. Critical Care 2012, **16**:225

Clement and colleagues conducted a study in 23 pediatric patients aged 0 to 24 months with a diagnosis of bronchiolitis presenting respiratory failure requiring MV. They compared the neural trigger and the pneumatic trigger using similar NAVA assistance, and observed that the trigger delay, the ventilator response time, and the work of breathing were reduced by the neural trigger

As patient–ventilator synchrony is improved with NAVA, the children may require lower doses of sedation with this mode of MV which can reduce the time of MV

Intensive Care Med 2006, 32:1515-1522

J Intensive Care Med 2003, 18:139-145.

Original article

Non-invasive neurally adjusted ventilatory assist in preterm infants: a randomised phase II crossover trial

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Objective- To compare NIV-NAVA and NIV-PS in preterm infants on patient–ventilator synchrony.

Patients Preterm infants born <32 weeks.

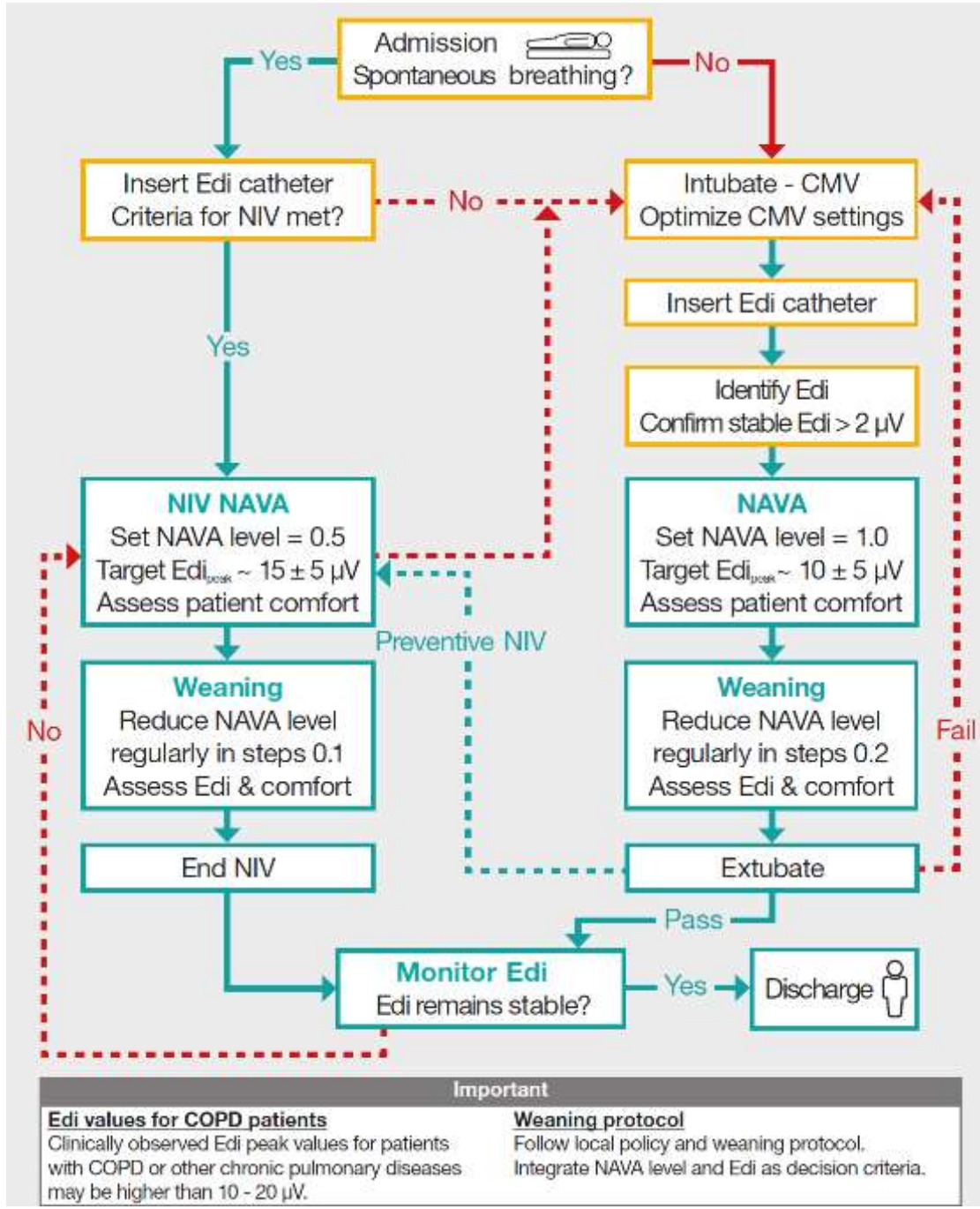
Intervention NIV-NAVA and NIV-PS were applied in random order after ventilator weaning. Data were recorded for sequential 5 min periods after 10 min applications of each mode

NAVA improved patient–ventilator synchrony and diaphragmatic unloading in preterm infants during non-invasive nasal ventilation even in the presence of large air leaks

NAVA may be an optimal option for NIPPV in very preterm infants who are at highest risks of intubation and poor respiratory outcomes

Table 2 Comparison of two methods of ventilation

	NIV-NAVA	NIV-PS	p Value
Main respiratory outcomes			
Trigger delay (ms)	35.2 (8.3)	294.6 (101.9)	<0.001
$Ti_{ventilator}$ (ms)	423.3 (87.1)	534.0 (165.5)	0.009
Ti_{neural} (ms)	347.2 (65.9)	389.7 (99.9)	0.11
Ti_{excess} (%)	32.2 (11.4)	56.8 (25.2)	0.001
PEEP (cm H_2O)	5.7 (0.6)	5.5 (0.6)	0.15
Mean airway pressure (cm H_2O)	7.7 (1.1)	8.0 (1.5)	0.47
Peak inspiratory pressure (cm H_2O)	12.3 (1.5)	14.7 (2.7)	0.003
Pneumatic RR (/min)	46.3 (12.6)	33.3 (13.1)	0.002
Minute ventilation (mL/kg/min)	114.9 (47.0)	124.1 (42.4)	0.74
Expiratory tidal volume (mL/kg)	2.6 (0.9)	4.0 (1.5)	0.09
Leakage (%)	87.6 (8.3)	86.7 (6.8)	0.67
Maximum Edi (μV)	12.6 (6.3)	16.6 (8.7)	0.003
Minimum Edi (μV)	3.8 (3.3)	4.2 (3.7)	0.62
Swing Edi (μV)	8.8 (4.8)	12.2 (8.7)	0.012
Asynchronies			
All asynchrony events (/min)	8.2 (3.0–11.5)	47.6 (38.1–61.1)	<0.001
Autotriggering (/min)	1.6 (0.3–4.0)	11.7 (8.0–16.5)	<0.001
Ineffective efforts(/min)	0.9 (0.2–1.2)	29.9 (24.8–50.5)	<0.001
Delayed cycling (/min)	2.2 (1.4–2.8)	1.3 (0.6–2.6)	0.53
Premature cycling (/min)	0.8 (0.4–1.8)	1.4 (1.1–1.8)	0.96
Double triggering (/min)	0.4 (0.2–1.9)	0 (0–0.9)	0.09
Double triggering, type I	0.1 (0–0.7)	0 (0–0)	0.036
Double triggering, type II	0.2 (0.2–0.8)	0 (0–0.3)	0.13
Asynchrony index, (%)	19.7 (9.6–23.4)	73.9 (71.5–78.1)	<0.001


Admission
Spontaneous breathing?
Yes
No
Insert Edi catheter
Criteria for NIV met?
No
Intubate - CMV
Optimize CMV settings
Insert Edi catheter
Identify Edi
Confirm stable Edi > 2 µV
Yes
NIV NAVA
Set NAVA level = 0.5
Target Edi peak ~ 15 ± 5 µV
Assess patient comfort
NAVA
Set NAVA level = 1.0
Target Edi peak ~ 10 ± 5 µV
Assess patient comfort
Preventive NIV
Weaning
Reduce NAVA level
regularly in steps 0.1
Assess Edi & comfort
Weaning
Reduce NAVA level
regularly in steps 0.2
Assess Edi & comfort
No
Fail
End NIV
Extubate
Pass
Monitor Edi
Edi remains stable?
Yes
Discharge
Important
Edi values for COPD patients
Clinically observed Edi peak values for patients with COPD or other chronic pulmonary diseases may be higher than 10 - 20 µV.
Weaning protocol
Follow local policy and weaning protocol.
Integrate NAVA level and Edi as decision criteria.

- TAKE HOME MESSAGE-
- Ventilator discontinuation process is an essential component of overall ventilator management.
- Undue delay leads to excess stay, iatrogenic lung injury, unnecessary sedation, and even higher mortality.
- Premature withdrawal can lead to muscle fatigue, dangerous gas exchange impairment, loss of airway protection, and also a higher mortality.
- Daily discontinuation assessment and management process for most ICU patients requiring at least 24 hours of mechanical ventilator support is recommended
- PSV and daily SBT are routine practice of weaning in our ICU.
- NIV is used in COPD patients immediately after extubation to prevent reintubation.

ASV can also be used for weaning to reduce duration of weaning and total duration of mechanical ventilation

NAVA can improve the problems of non-synchronization between the patient and the ventilator and the problems of risk of over ventilation in chronic obstructive pulmonary disease patients, or in case of rapid breathing frequency with a very small tidal volume in pediatric patients.

- But long term outcome with NAVA in patients of weaning failure is yet to be defined.