réanimation 2017
PARIS 11-13 JANVIER
srlf
SOCIÉTÉ DE RÉANIMATION DE LANGUE FRANÇAISE
SKR
Société de Kinésithérapie de Réanimation

NOUVELLES TECHNOLOGIES EN RÉANIMATION : AUTOMATISATION DE LA VENTILATION MÉCANIQUE

Emilie Bialais,
Emilie.Bialais@uclouvain.be
Kinésithérapeute, PhD Student
Médecine Physique, Soins Intensifs,
Cliniques universitaires Saint-Luc,
Bruxelles

Cliniques universitaires
SAINT-LUC
UCL BRUXELLES

Déclaration de liens

Soutien matériel :

Hamilton Medical AG, Bonaduz, Switzerland

A servomechanism for automatic regulation of pulmonary ventilation.
J Appl Physiol. **1957** Sep;11(2):326-8.

AUTOMATIC REGULATION OF ARTIFICIAL PULMONARY VENTILATION

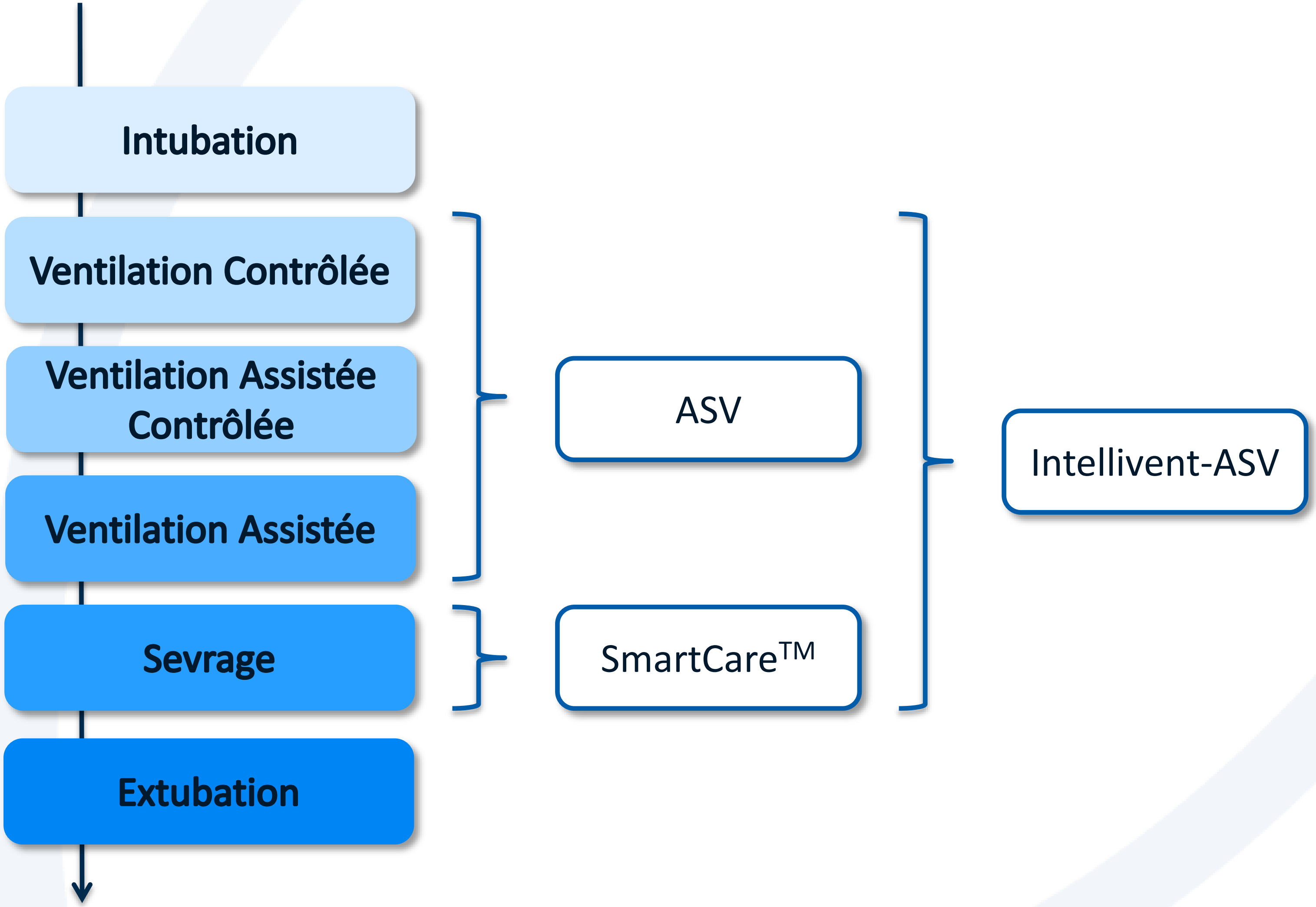
T. M. Darbinjan

Acta Anaesthesiol Scand Suppl. **1966**;23:187-90.

Table 1. The Argument for Closed Loop Control and Automating the Weaning Process

Costs	
	Mechanical ventilation is expensive, contributing substantially to health care costs[10,24-26]
	Mechanical ventilation is associated with significantly higher daily costs for patients in the ICU throughout their entire stay.[10]
	Interventions that result in reduced duration of mechanical ventilation could lead to substantial reductions in total in-patient cost.
Increased Demand	
	Increase in the population requiring intensive care and mechanical ventilation; increased requirement for prolonged mechanical ventilation[27-29]
	The aging population and demand for healthcare at later age increases mechanical ventilation demand.
	Prolonged mechanical ventilation demand is expected to double from 2000 to 2020.[28]
	In growing populations the need for mechanical ventilation is predicted to grow by 80%.[29]
Staffing Issues	
	Growing shortage of ICU workforce[27,30]
	Increased incidence of burnout in the ICU workforce[31-35]; changes in work hour restrictions[36]
	A multi-society report predicts a looming shortage of intensivists and respiratory therapists.[27]
	The intensity of ICU care results in burnout in nursing and other bedside staff, resulting in turnover and high dissatisfaction.
	In academic centers, resident work hours impact physician availability.
Knowledge Implementation[37-40]	
	Failure to use evidenced based care in the ICU[37,38]
	Prolonged time from publication of seminal study until routine implementation[38-40]
	Barriers to change by healthcare professionals from both physicians and bedside caregivers[41-44]
	Evidence suggests that nearly 20 years pass from publication of new data until adoption by > 50% of caregivers.
	ICU staff list numerous reasons for not using low tidal volume ventilation or daily spontaneous breathing trials.
	Adoption of new knowledge in any field
Outcomes	
	Failure to implement current state of the art knowledge into practice
	Errors increase with increases in patient acuity and staff shortages
	High intensity of ICU and mechanical ventilation increases incidence of errors
	Data suggest that just over half of patients in the United States receive recommended care, leading to increased complications and costs.[41]
	Failure to deliver evidence-based care, which has been demonstrated to reduce mortality, results in nearly 200,000 preventable deaths.[42]
	Closed loop control has the promise of reducing practice variation and providing state of the art care.

Branson. Respiratory Care 2012:57(10)


Intubation
Ventilation Contrôlée
Ventilation Assistée Contrôlée
Ventilation Assistée
Sevrage
Extubation
ASV
SmartCare™
Intellivent-ASV

Intubation

Ventilation Contrôlée

Ventilation Assistée Contrôlée

Ventilation Assistée

Sevrage → SmartCare™

Extubation

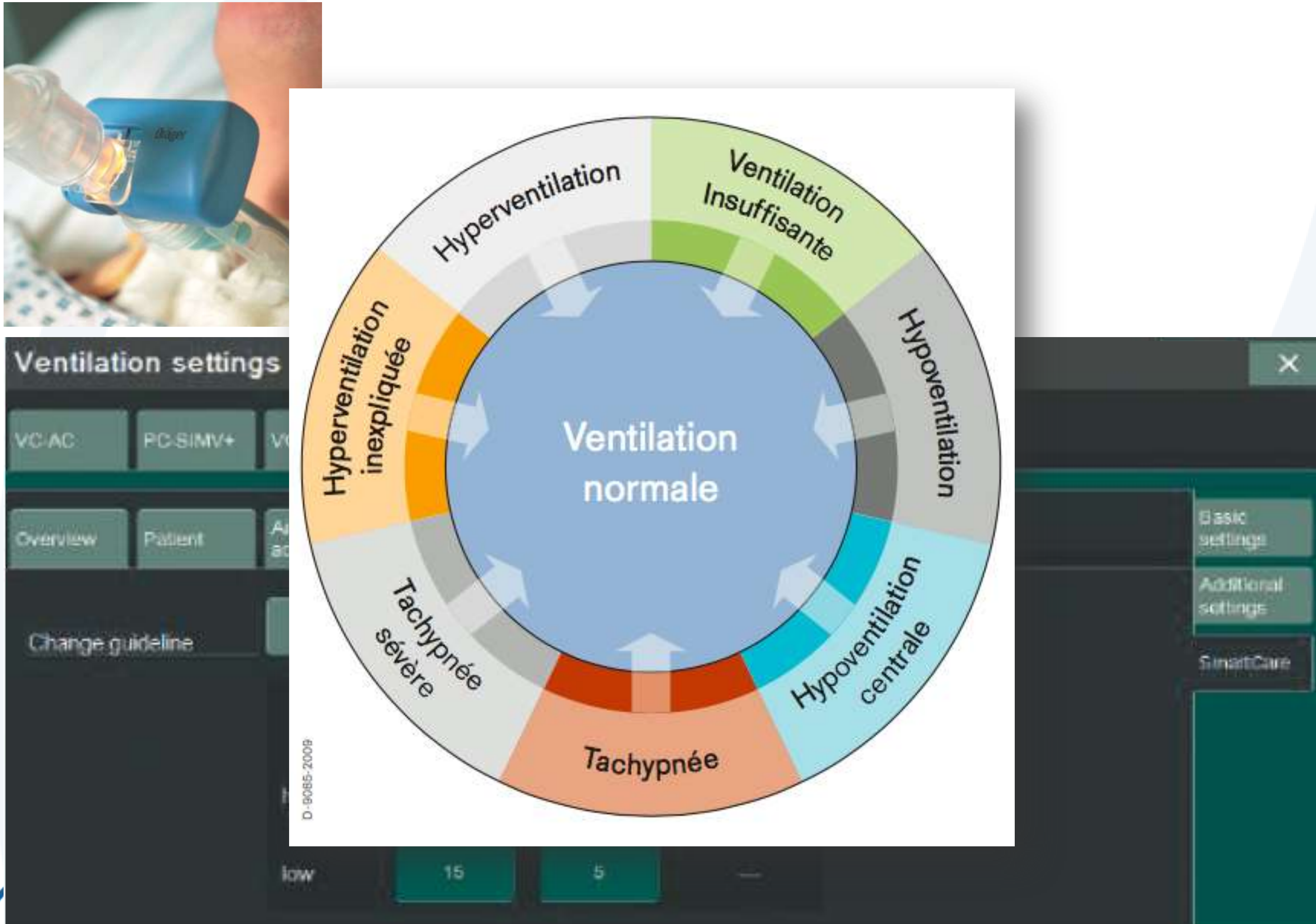

Ventilation settings
VC-AC
PC-SIMV+
Overview
Patient
Change guideline
Basic settings
Additional settings
SmartCare
low
15
5
Hyperventilation
Ventilation Insuffisante
Hypoventilation
Hypoventilation centrale
Tachypnée
Tachypnée sévère
Hyperventilation inexpliquée
Ventilation normale
D-9085-2009

TABLE 4. SECONDARY OUTCOMES

Secondary Outcomes	Automated Weaning	Protocolized Weaning	*P* Value
Time to first SBT, d (median, IQR), N	0 (0, 2.0), 39	1.0 (0, 3.0), 40	0.5
Time to firs			<0.0001
Time to firs			0.02
Time to suc			0.01
Total durati			0.13
ICU stay (ac			
Survivors			0.1
Survivors			0.48
Hospital sta			
Survivors			0.7
Survivors			0.41
ICU stay (ra			
Survivors			0.04
Survivors			0.18
Hospital sta			
Survivors			0.6
Survivors			0.23
Time to rei			0.04
Required N			0.5
Developed			0.7
ICU mortali			0.8
Hospital m			0.9
Death on r			0.8
Reintubatio			0.4
Tracheosto			0.04
Prolonged			0.04
Ventilator d… at 90 d, n			1.0

Definition of abbreviations: CIN = critical illness neuropathy; ICU = intensive care unit; IQR = interquartile range; NIV = noninvasive ventilation; SBT = spontaneous breathing trial.

N = number of patients used for the outcome analysis.

* Seven deaths in the automated weaning group, two withdrawals, and nine deaths in the protocolized weaning group do not have a date of successful extubation.

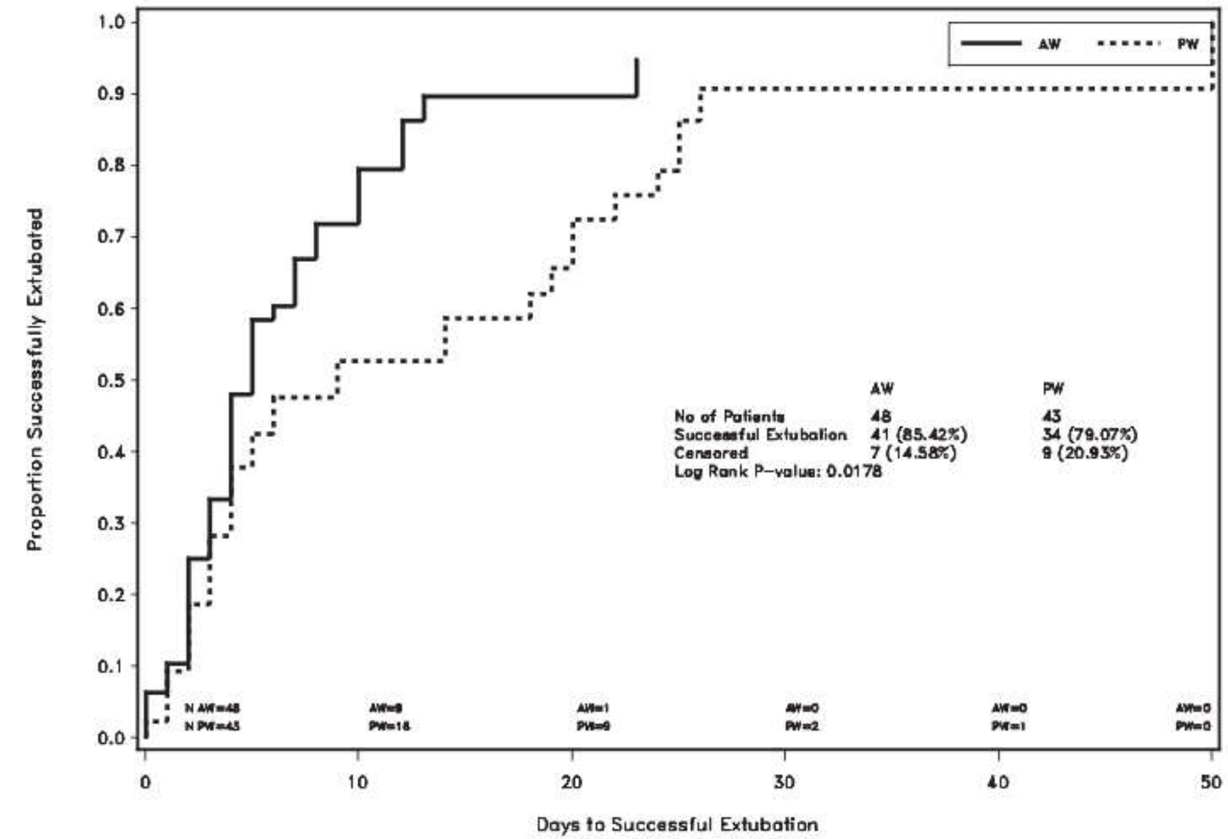


Figure 2. Time to successful extubation for the two treatment groups (Kaplan-Meier curves). AW = automated weaning; PW = protocolized weaning.

Intubation

Ventilation Contrôlée

Ventilation Assistée Contrôlée

Ventilation Assistée

Sevrage

Extubation

ASV

Mechanics of Breathing in Man[1]

ARTHUR B. OTIS, WALLACE O. FENN AND HERMANN RAHN. *From the Department of Physiology and Vital Economics, University of Rochester School of Medicine and Dentistry, Rochester, New York*

J Appl Physiol. 1950 May;2(11):592-607.

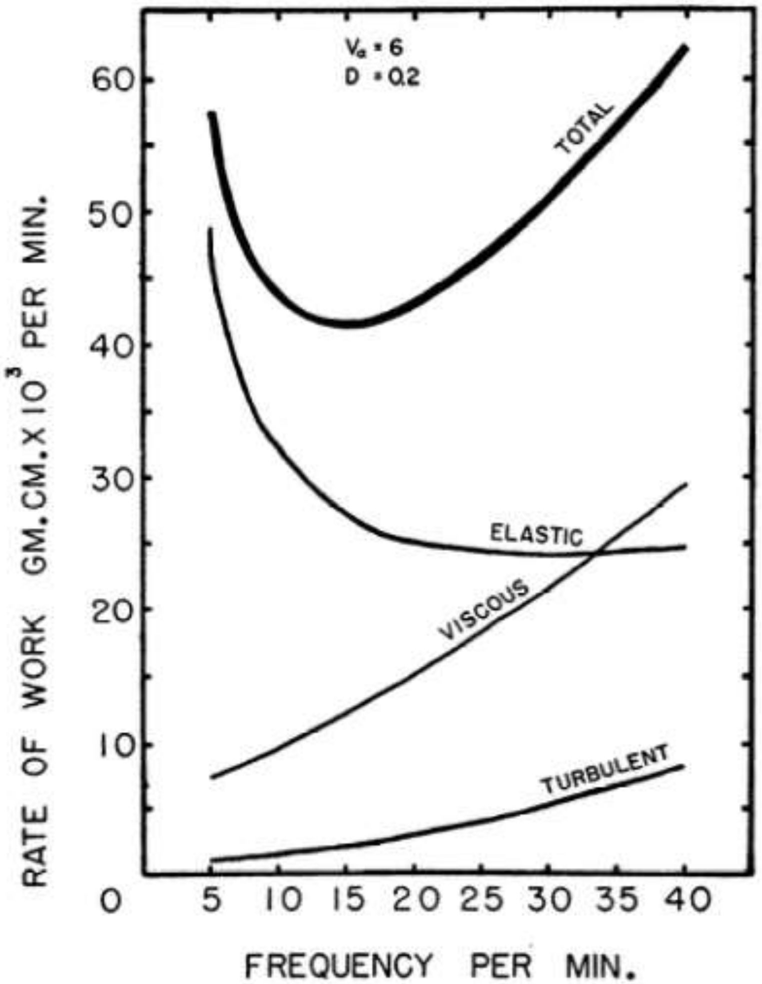
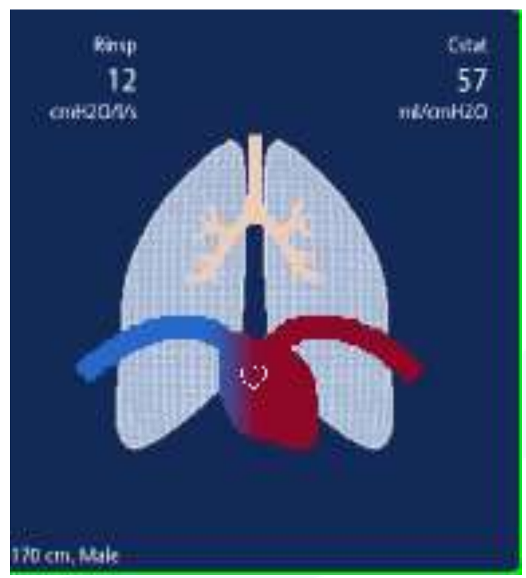
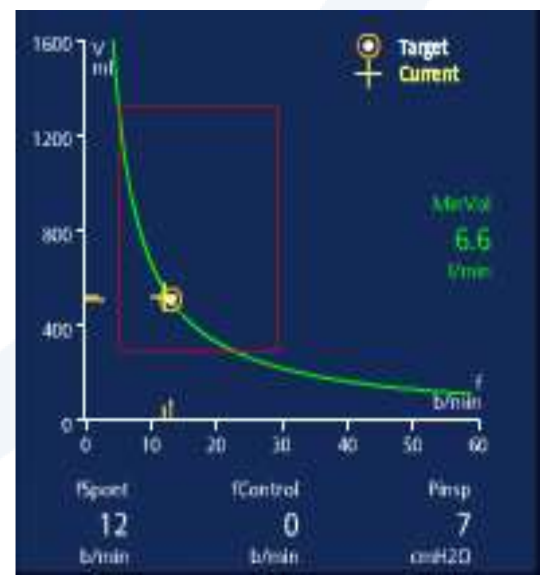


Fig. 7. RELATIONSHIP of elastic, viscous, turbulent, and total work of breathing/min. to frequency of breathing when alveolar ventilation is 6 l/min., and dead space is 200 cc. Curves calculated according to *equation 13*.

Otis Equation

$$f = \frac{1 + 2a \times \mathrm{RC} \times \frac{\mathrm{Min\ Vol} - (f \times V_d)}{V_d} - 1}{a \times \mathrm{RC}}$$





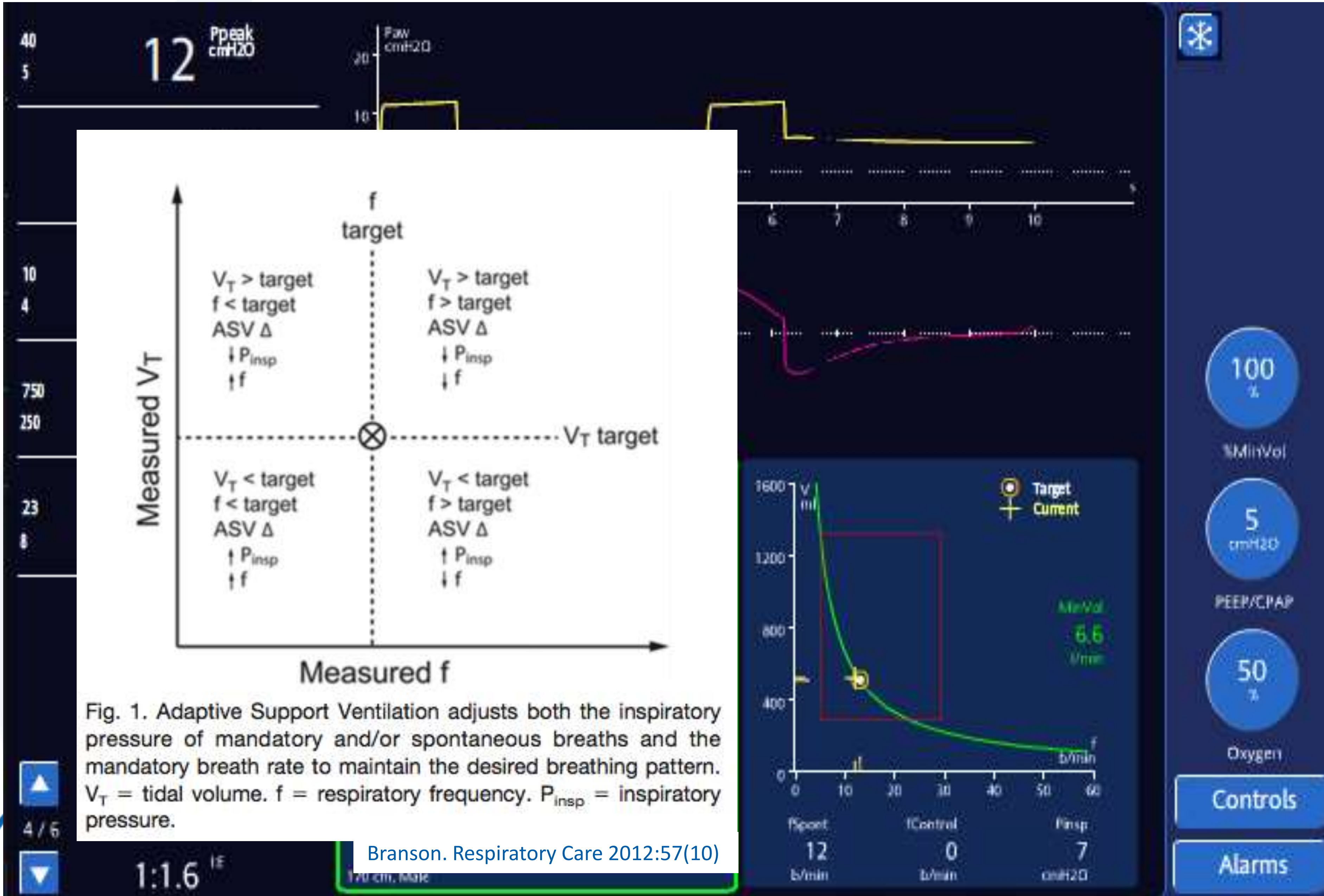


Fig. 1. Adaptive Support Ventilation adjusts both the inspiratory pressure of mandatory and/or spontaneous breaths and the mandatory breath rate to maintain the desired breathing pattern. V_T = tidal volume. f = respiratory frequency. P_{insp} = inspiratory pressure.

Branson. Respiratory Care 2012:57(10)

Effects of Implementing Adaptive Support Ventilation in a Medical Intensive Care Unit

Chien-Wen Chen MD, Chin-Pyng Wu MD PhD, Yu-Ling Dai, Wann-Cherng Perng MD, Chih-Feng Chian MD, Wen-Lin Su MD, and Yuh-Chin T Huang MD MHS

RESPIRATORY CARE • JULY 2011 VOL 56 NO 7

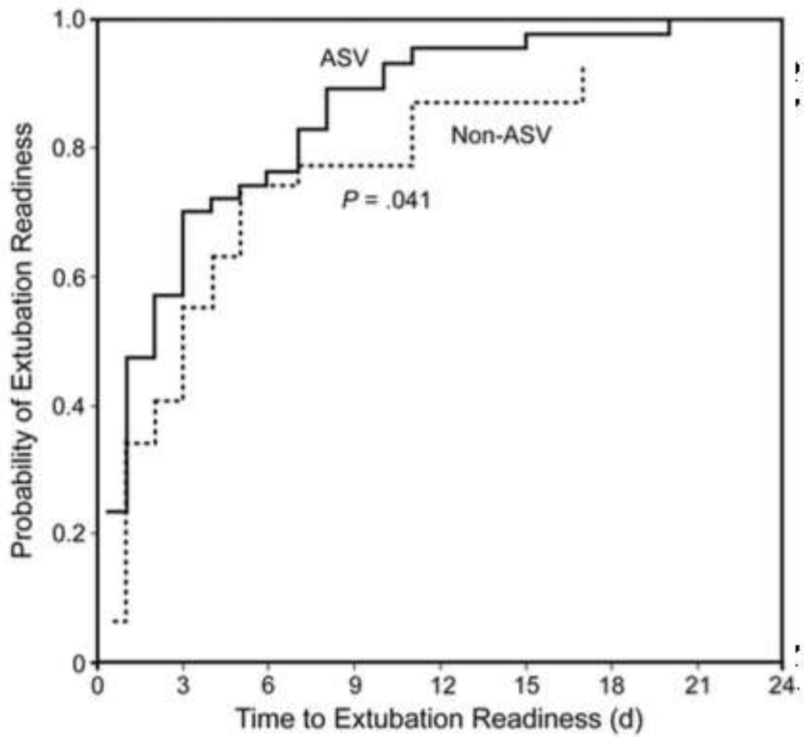


Fig. 3. Cumulative incidence of the probability of reaching extubation readiness (see text) after enrollment.

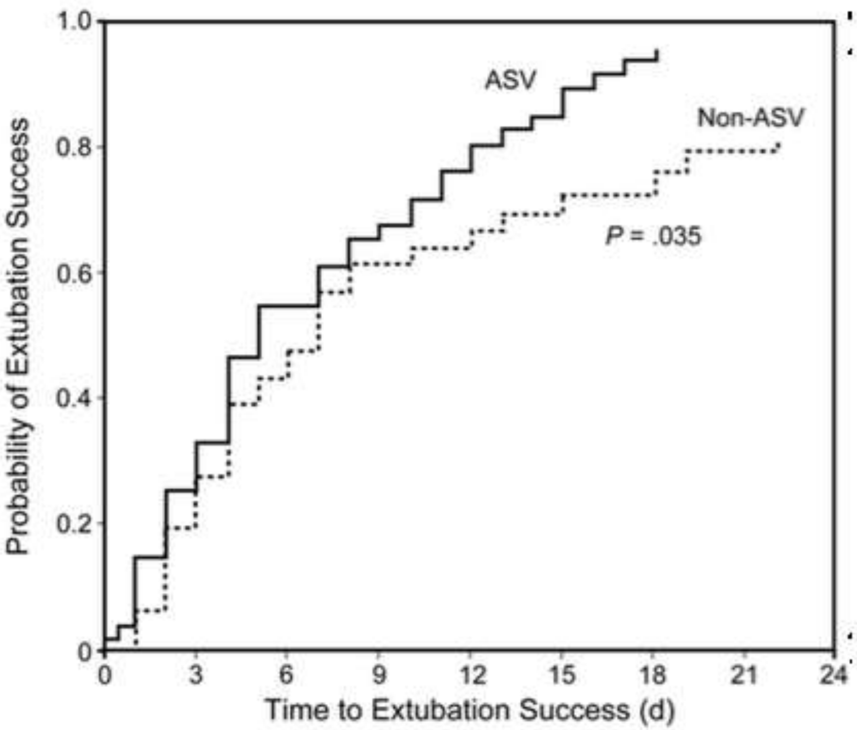


Fig. 4. Cumulative incidence of the probability of extubation success (see text) after enrollment.

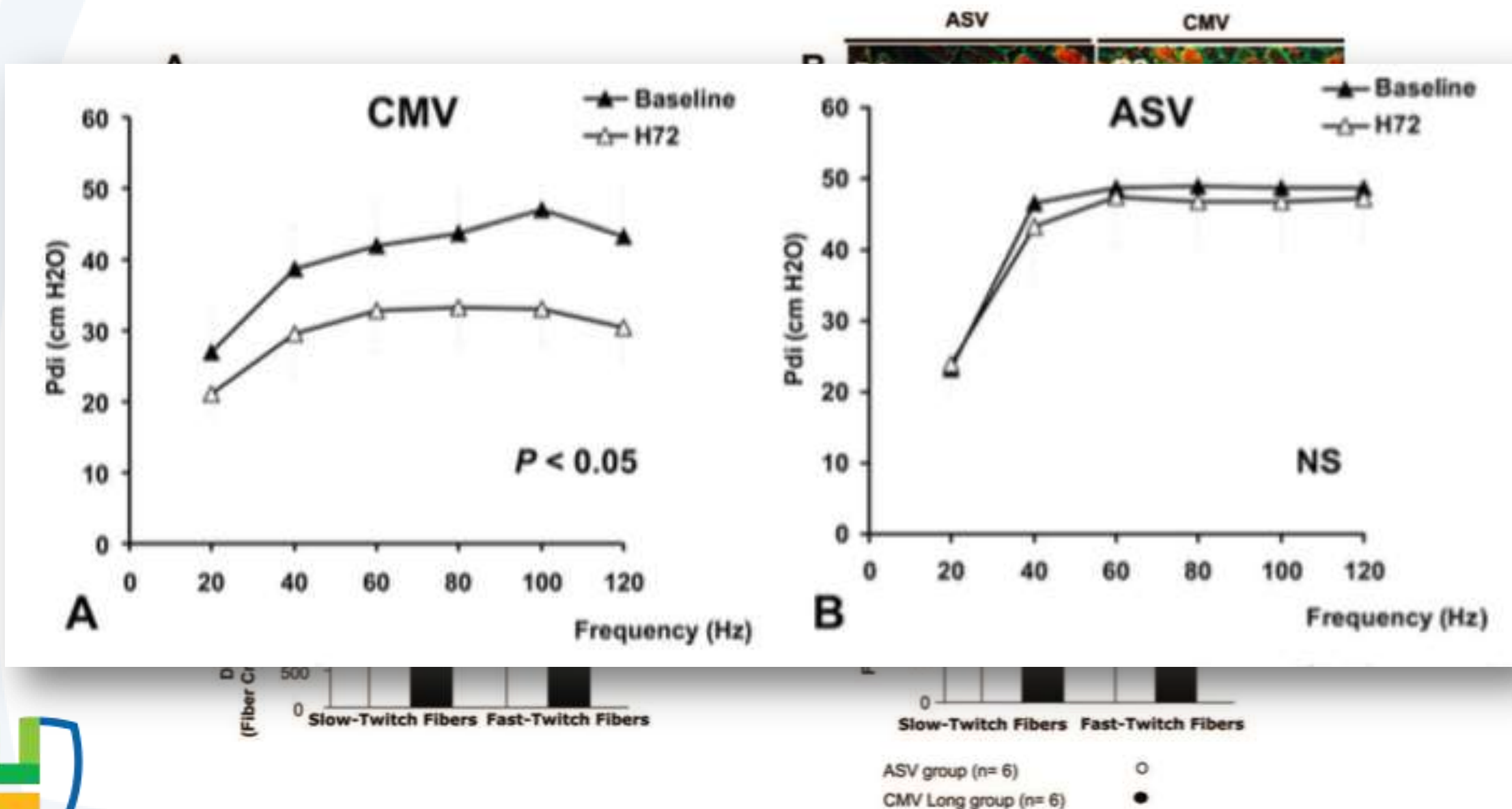
In conclusion, the similarities in our short-term comparison between ASV and CV in passively ventilated patients were more impressive than the differences. Compared with CV set clinically, ASV was associated with more efficient CO_2 elimination in 35% of cases, slightly lower ventilator work of inspiration, and slower and deeper ventilatory pattern especially evident in obstructed patients. The ASV algorithm applied a ventilatory pattern that was driven by the type and severity of the derangement in the patient's respiratory system mechanics and thus mimicked the approach taken by clinicians in setting CV. In three COPD patients, very high Vt was observed, possibly related to the set pressure limit. In all other cases the ASV algorithm resulted in ventilatory settings within reasonably safe limits [39, 40]. Whether ASV will improve clinical outcomes of patients with acute respiratory failure still must be addressed in future studies.

Iotti et al. Intensive Care Med (2010) 36:1371–1379

Adaptive Support Ventilation Prevents Ventilator-induced Diaphragmatic Dysfunction in Piglet

An In Vivo *and* In Vitro *Study*

Boris Jung, M.D.,* Jean-Michel Constantin, M.D., Ph.D.,† Nans Rossel, M.D.,‡
Charlotte Le Goff, M.D.,‡ Mustapha Sebbane, M.D.,* Yannael Coisel, M.D.,‡
Gerald Chanques, M.D.,* Emmanuel Futier, M.D.,§ Gerald Hugon,‖ Xavier Capdevila, M.D., Ph.D.,#
Basil Petrof, M.D., Ph.D.,** Stefan Matecki, M.D., Ph.D.,†† Samir Jaber, M.D., Ph.D.‡‡



Anesthesiology 2010; 112:1435–43

Study or Subgroup	Automated Mean [log days]	Automated SD [log days]	Automated Total	Non-automated Mean [log days]	Non-automated SD [log days]	Non-automated Total	Weight	Mean Difference IV, Random, 95% CI [log days]
1.11.1 Mixed or medical ICU population								
Agarwal 2013	2.08	0.63	23	2.2	0.92	25	3.0%	-0.12 [-0.56, 0.32]
Burns 2013	2.83	0.36	49	2.94	0.93	43	5.7%	-0.11 [-0.41, 0.19]
Jouvet 2013	2.05	0.62	15	2.52	0.79	15	2.3%	-0.47 [-0.98, 0.04]
Kirakli 2011	2.3	0.57	49	2.39	0.43	48	9.5%	-0.09 [-0.29, 0.11]
Lellouche 2006	2.48	0.87	74	2.91	0.75	70	6.7%	-0.43 [-0.69, -0.17]
Liu 2013	2.64	0.9	19	3.35	1.13	20	1.5%	-0.71 [-1.35, -0.07]
Rose 2008	1.92	0.68	51	2.02	0.77	51	6.1%	-0.10 [-0.38, 0.18]
Xirouchaki 2008	2.67	0.66	108	2.66	0.68	100	10.5%	0.01 [-0.17, 0.19]
Subtotal (95% CI)			**388**			**372**	**45.4%**	**-0.18 [-0.32, -0.04]**
Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 12.24$, df = 7 (P = 0.09); $I^2 = 43\%$								
Test for overall effect: Z = 2.45 (P = 0.01)								
1.11.2 Surgical ICU population								
Aghadavoudi 2012	0.11	0.12	41	0.08	0.09	40	20.4%	0.03 [-0.02, 0.08]
Dongelmans 2009	0.36	0.63	64	0.49	0.64	64	8.5%	-0.13 [-0.35, 0.09]
Petter 2003	-0.04	0.16	18	-0.03	0.62	16	5.3%	-0.01 [-0.32, 0.30]
Schädler 2012	1.15	1.49	150	1.26	1.67	150	4.3%	-0.11 [-0.47, 0.25]
Sulzer 2001	-0.11	0.15	16	-0.13	0.17	20	16.1%	0.02 [-0.08, 0.12]
Subtotal (95% CI)			**289**			**290**	**54.6%**	**0.02 [-0.02, 0.06]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.51$, df = 4 (P = 0.64); $I^2 = 0\%$								
Test for overall effect: Z = 0.98 (P = 0.33)								
Total (95% CI)			**677**			**662**	**100.0%**	**-0.08 [-0.16, 0.00]**
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 23.66$, df = 12 (P = 0.02); $I^2 = 49\%$								
Test for overall effect: Z = 1.93 (P = 0.05)								
Test for subgroup differences: $Chi^2 = 6.92$, df = 1 (P = 0.009), $I^2 = 85.6\%$								

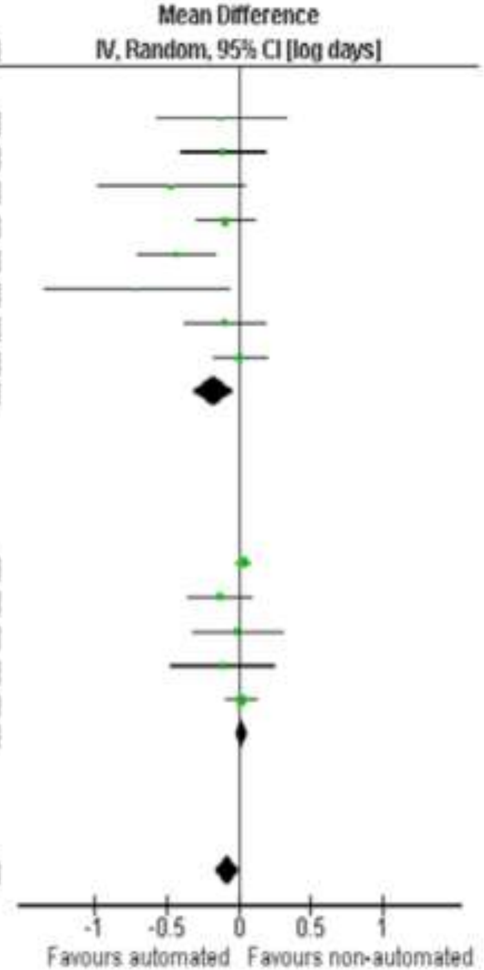


Figure 8 ICU length of stay by study population.

Name of the ventilation mode	Advantages/Main features	Disadvantages/Remarks
Adaptive support ventilation (ASV)	Patented closed-loop feedback technique. Automatically adjusts tidal volume and respiratory rate based on a calculated minute ventilation and measured respiratory mechanics to minimize the work rate of breathing. Can be used for full and assist ventilatory control. Provides pressure controlled ventilation to deliver a target tidal volume	Does not push for weaning. Minute ventilation is not adjusted continuously. PEEP and F_{IO_2} are manually controlled
SmartCare	A protocol-driven automatic system for control of weaning in the PS mode. Automatically and incrementally adjusts the pressure support level based on measurement of respiratory rate, tidal volume, and P_{etCO_2}. If measured values are in the specified "comfort zone," it pushes for weaning by incrementally reducing the pressure support level	Uses fixed rules. The changes in respiratory mechanics do not affect the acceptable ranges of respiratory rate and tidal volume. Does not guarantee delivery of minimum ventilation. PEEP and F_{IO_2} are manually controlled

Interaction patient – respirateur
Titration et adaptation en continu

Cibles « irréalisables »
Modèle physiologique complexe

Incorporent monitoring + poussé que modes conventionnels
+ système de détection des artefacts

D'après Tehrani, Journal of Clinical Monitoring and Computing (2008) 22:417–424

Intubation

Ventilation Contrôlée

Ventilation Assistée Contrôlée

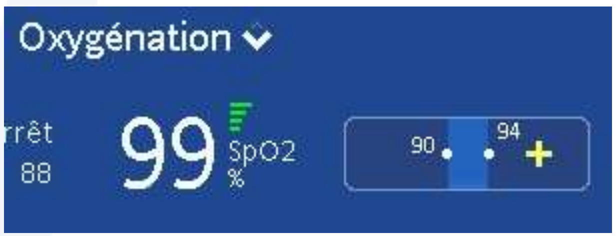
Ventilation Assistée

Sevrage

Extubation

Intellivent-ASV

Intellivent-ASV ⇨ ASV +



2012-10-09 11:56:32
Options
Mode
ASV
Adulte
Patient
INTELLiVENT
40
25 P crête cmH2O
30
4
9.4 VolMinExp l/min
1050
604 VTE ml
51
Arrêt
88
Élimination CO2
P crête
50
70
90
40
Réglages automatique
%VolMin Automatique Manuel
PEP Automatique Manuel
Oxygène Automatique Manuel
Critères patient
Sevrage rapide
SDRA
Toujours
Hypercp. chr.
Conditionnel
Lésion céréb.
Désactivé
Recrutement auto
Réglage limite PEP
Pt passif
Sans recrut.
15 cmH2O
Limite PEP
HLI activé
Tendance
Vue 1/3
IntelliCuff
100 % %VolMin
12 cmH2O PEP
48 % Oxygène
48
Réglages
Alarmes
Oxygenation
CO2 elimination
Spont/Activity
00:03
8
9.9
100
75
21
0
3.3
0
100
00:08
00:15
00:15
00:06
00:04
00:04
Oxygen 40 %
PEEP/CP/ 5 cmH2O
ExpMinV 8.5 l/min
Pinsp 8 cmH2O
RSB 23 1/(min x l
%fSpont 100 %
9.4 VolMinExp l/min
4 / 11
9.4 VMSpont l/min
0
93
97
0
Target Shift
SpO2
Monitorage
Graphiques
Outils
Évènements
Système
USB
INT
CA

Arnal et al. Critical Care 2013, 17:R196
http://ccforum.com/content/17/5/R196

CRITICAL CARE

RESEARCH Open Access

Feasibility study on full closed-loop control ventilation (IntelliVent-ASV™) in ICU patients with acute respiratory failure: a prospective observational comparative study

Jean-Michel Arnal[1,2*], Aude Garnero[1], Dominik Novonti[2], Didier Demory[1], Laurent Ducros[1], Audrey Berric[1], Stéphane Yannis Donati[1], Gaëlle Corno[1], Samir Jaber[3] and Jacques Durand-Gasselin[1]

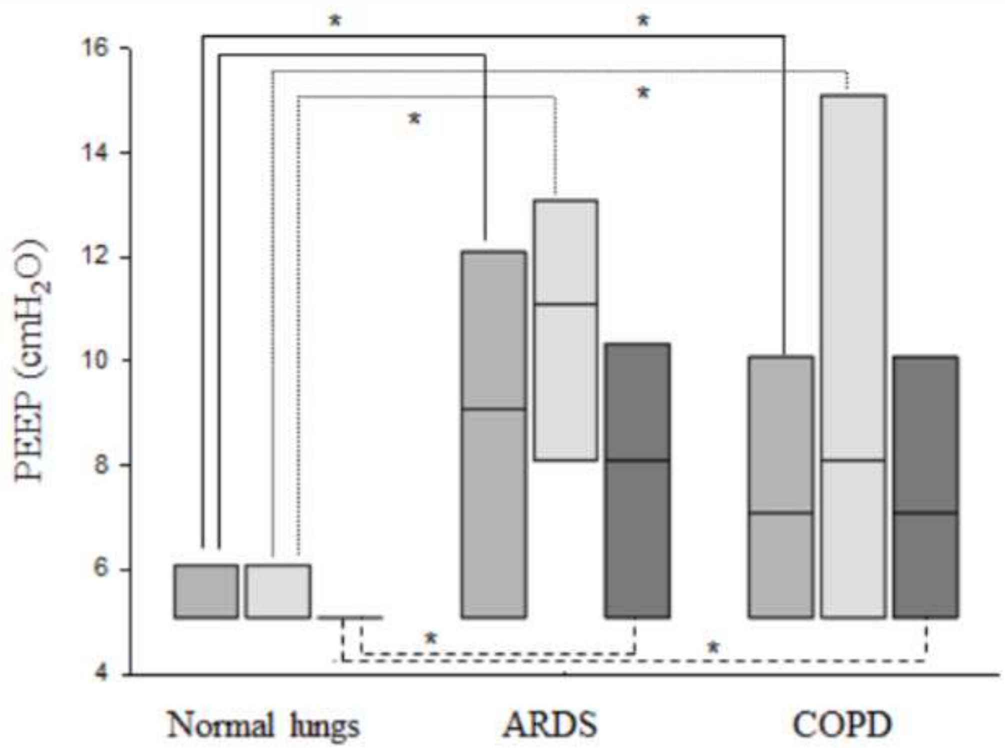


Figure 4 PEEP selected by IntelliVent-ASV™: PEEP for normal lung patients, ARDS and COPD patients. For each lung condition, all patients, passive patients and active patients are shown on the left, middle and right box plot, respectively. Comparisons used a Kruskal-Wallis analysis of variance with a Dunn's post hoc test. *$P \leq 0.05$. ARDS, acute respiratory distress syndrome; COPD, chronic obstructive pulmonary disease; PEEP, positive end-expiratory pressure (cmH_2O).

...h lung condition, all patients, ...d a Kruskal-Wallis analysis of variance with a Dunn's post hoc test. *$P \leq 0.05$. ARDS, acute respiratory distress syndrome; COPD, chronic obstructive pulmonary disease; FiO_2, inspiratory fraction of oxygen (%).

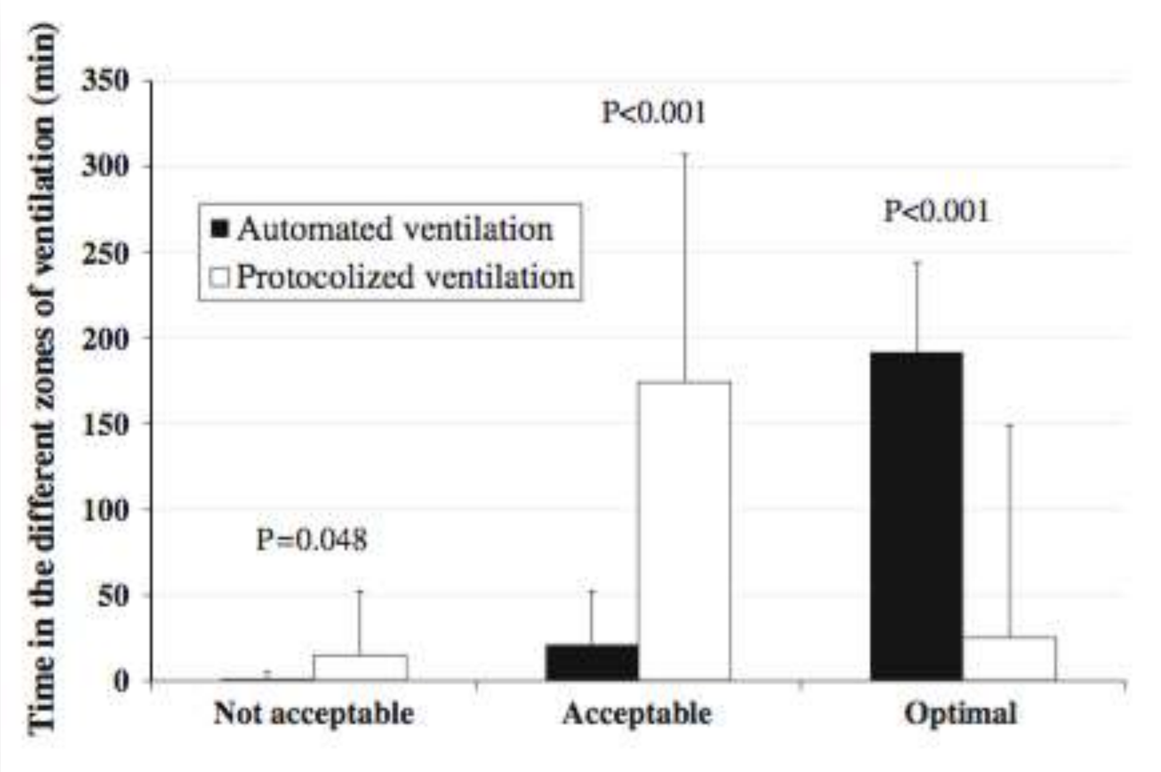
Figure 2 Tidal volume sel... COPD patients. For each lu... respectively. Comparisons used a Kruskal-Wallis analysis of variance with a Dunn's post hoc test. *$P \leq 0.05$. ARDS, acute respiratory distress syndrome; COPD, chronic obstructive pulmonary disease.

Intensive Care Med (2013) 39:463–471
DOI 10.1007/s00134-012-2799-2

ORIGINAL

François Lellouche
Pierre-Alexandre Bouchard
Serge Simard
Erwan L'Her
Marc Wysocki

Evaluation of fully automated ventilation: a randomized controlled study in post-cardiac surgery patients

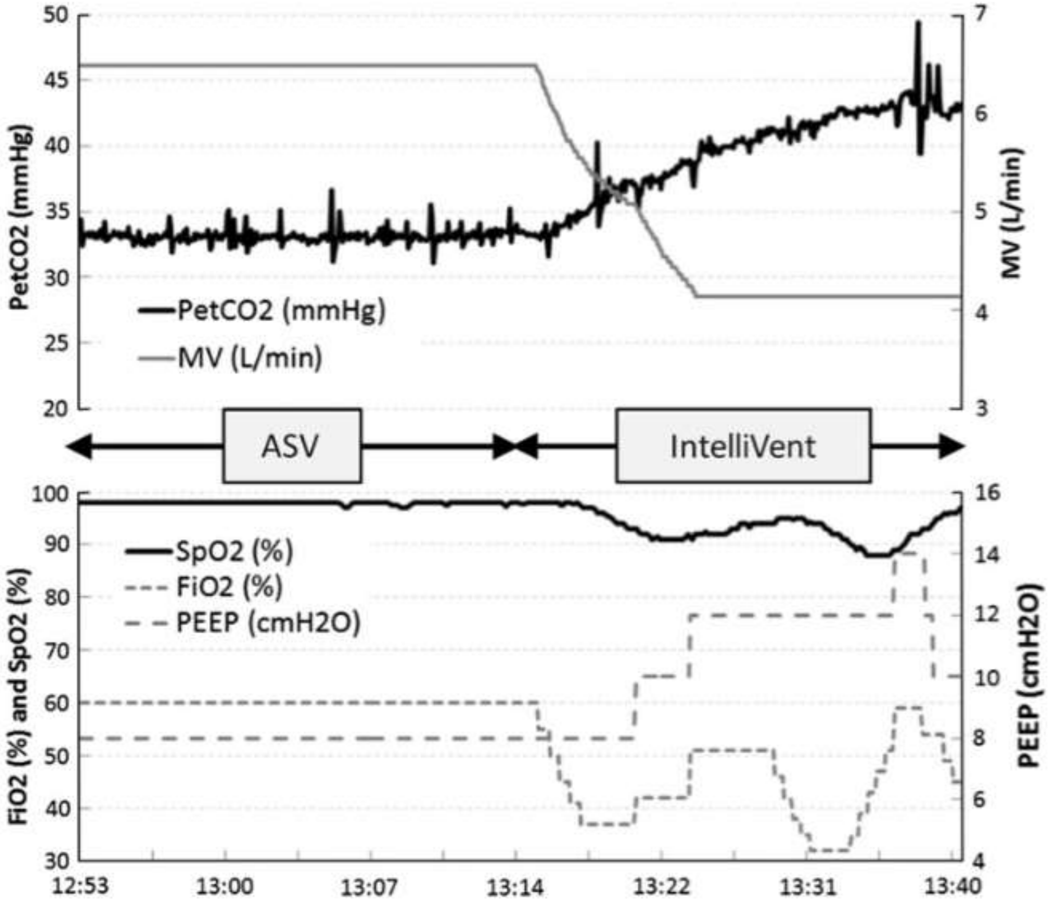


Intensive Care Med (2012) 38:781–787
DOI 10.1007/s00134-012-2548-6

ORIGINAL

Safety and efficacy of a fully closed-loop control ventilation (IntelliVent-ASV®) in sedated ICU patients with acute respiratory failure: a prospective randomized crossover study

Fig. 2 Changes in minute ventilation (MV), FiO_2 and PEEP during adaptive support ventilation (ASV) and IntelliVent-ASV® periods of ca. 30 min in a representative patient (patient #10) with acute lung injury. During the ASV period, there was no change in MV, FiO_2 or PEEP. During the IntelliVent-ASV® period, MV decreased progressively from 6.5 to 4 L/min to increase E_TCO_2 from 33 to 43 mmHg (*top panel*). FiO_2 was initially reduced but SpO_2 decreased to 90 %. PEEP and FiO_2 were readjusted to finally achieve an SpO_2 of 95 % with FiO_2 44 % and PEEP 10 cmH_2O as compared to FiO_2 60 % and PEEP 8 cmH_2O with ASV (*lower panel*)



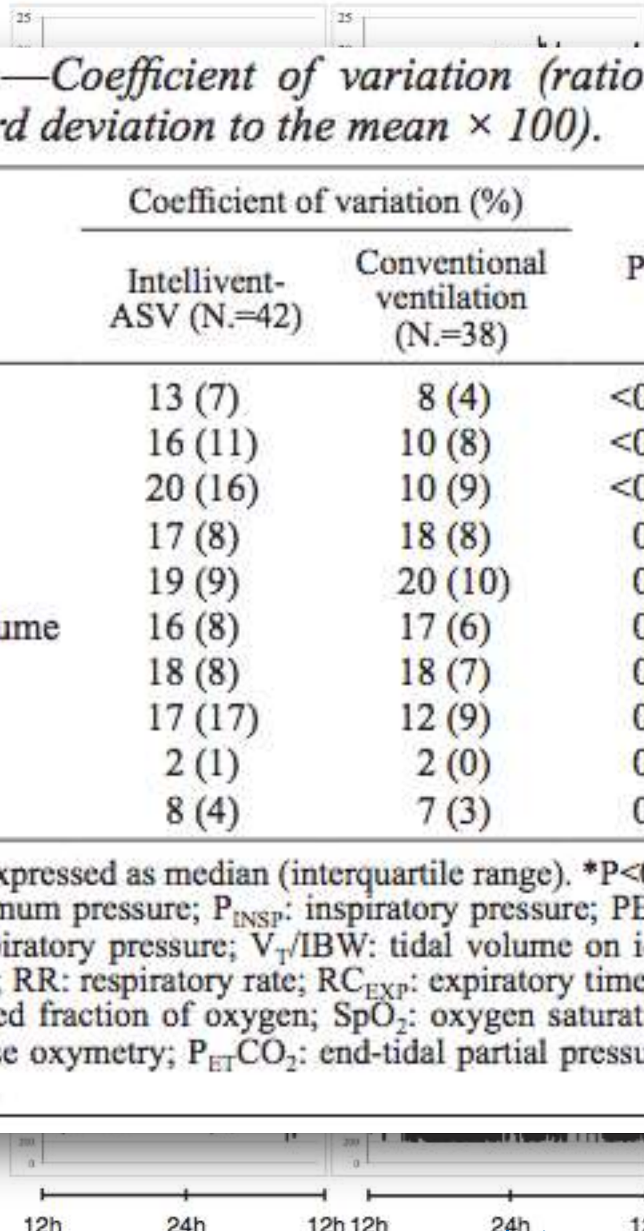


TABLE V.—*Coefficient of variation (ratio of the standard deviation to the mean × 100).*

	Coefficient of variation (%)		
	Intellivent-ASV (N.=42)	Conventional ventilation (N.=38)	P value
P_{MAX}	13 (7)	8 (4)	<0.001*
P_{INSP}	16 (11)	10 (8)	<0.001*
PEEP	20 (16)	10 (9)	<0.001*
V_T/IBW	17 (8)	18 (8)	0.161
RR	19 (9)	20 (10)	0.314
Minute volume	16 (8)	17 (6)	0.874
RC_{EXP}	18 (8)	18 (7)	0.821
FiO_2	17 (17)	12 (9)	0.056
SpO_2	2 (1)	2 (0)	0.030*
$P_{ET}CO_2$	8 (4)	7 (3)	0.230

Values are expressed as median (interquartile range). *P<0.05.
P_{MAX}: maximum pressure; P_{INSP}: inspiratory pressure; PEEP: positive end-expiratory pressure; V_T/IBW: tidal volume on ideal body weight ratio; RR: respiratory rate; RC_{EXP}: expiratory time constant; FiO_2: inspired fraction of oxygen; SpO_2: oxygen saturation measured by pulse oxymetry; $P_{ET}CO_2$: end-tidal partial pressure of carbon dioxide.

Bialais et al. Minerva anestesiologica 2016;82(6):657-68

Clavieras et al. Anesthesiology 2013; 119:631-41

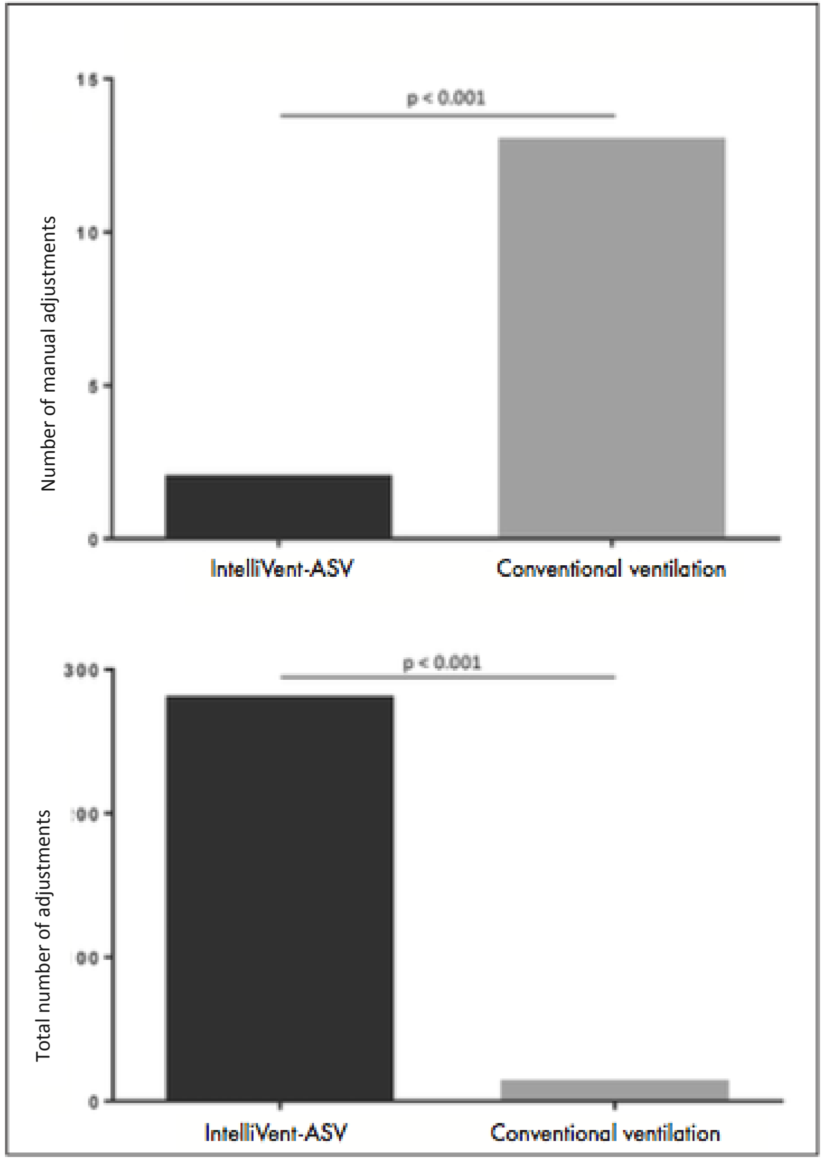


Figure 3.—Number of adjustments on the ventilator throughout the 48-hour ventilation: A) number of manual adjustments; B) total number of adjustments (including automatic adaptations).

Intubation

Ventilation Contrôlée

Ventilation Assistée Contrôlée

Ventilation Assistée

Sevrage

Extubation

ASV

SmartCare™

Intellivent-ASV

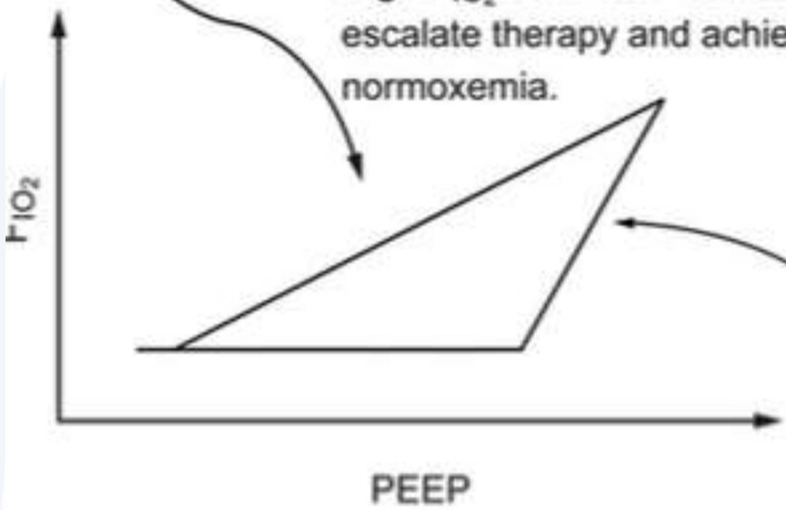
Les modes automatisés :

- permettent pour un grand nombre de patients, une ventilation similaire à celle réglée par le clinicien
- pourraient être une aide dans les unités surchargées

Merci de votre attention !

F_{IO_2}	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18-24

High F_{IO_2}/low PEEP table to escalate therapy and achieve normoxemia.



Low F_{IO_2}/high PEEP table to minimize oxygen exposure and maintain lung volume after initial stabilization

F_{IO_2}	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5-	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	5	8	10	12	14	14	16	16	18	20	22	22	22	24

S_{pO_2} target is adjustable by the caregiver.

A high PEEP limit can be set to allow greater control by the clinician if desired. At the PEEP limit only F_{IO_2} is increased to meet S_{pO_2} goals.

Branson. Respiratory Care 2012:57(10)