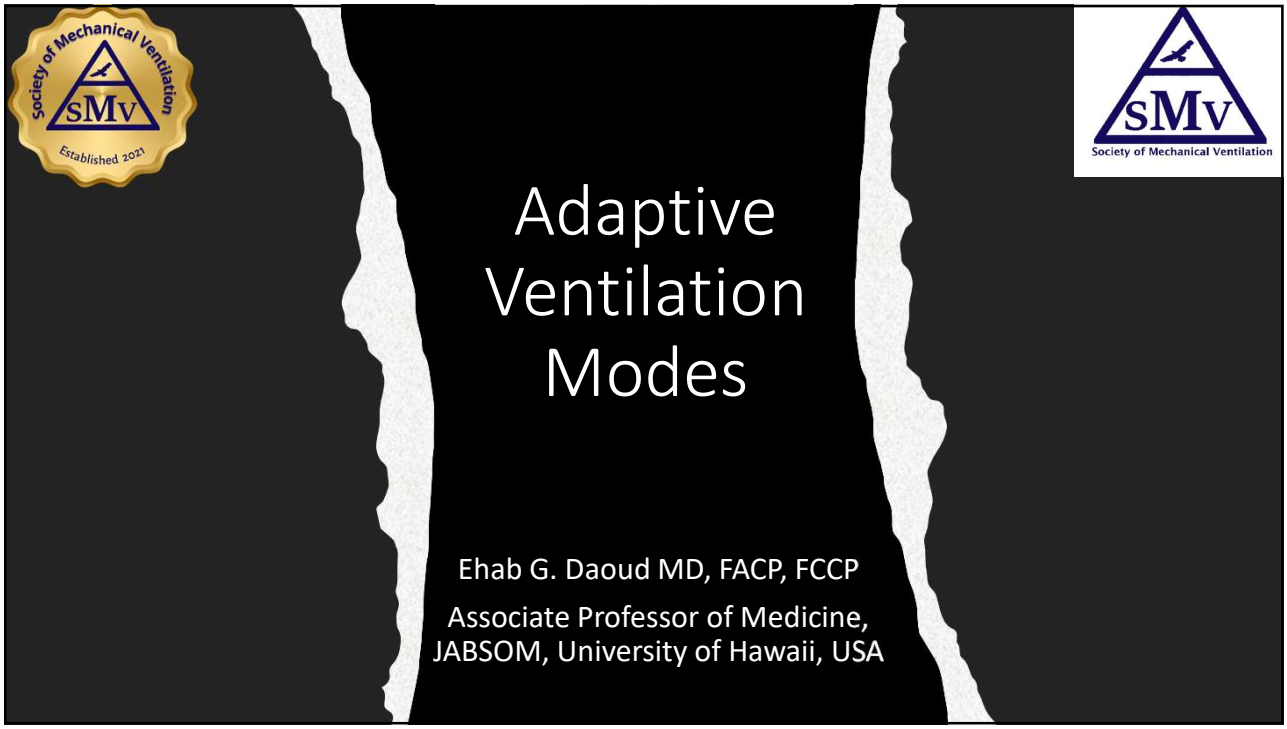


1

Objectives

- What are Adaptive modes
- How they work
- Why use them
- Evidence

2

What are Adaptive modes

- Closed-Loop system (Positive and Negative feedback)
- Optimal/Intelligent Targeting Scheme (Best settings)
- Adaptive: Adapt to patients' respiratory mechanics and ventilatory patterns
- Not one mode:
  - Passive patient: Pressure Controlled mode
  - Spontaneous breaths less than target: Intermittent Mandatory mode
  - Spontaneous breaths more than target: Pressure Support mode

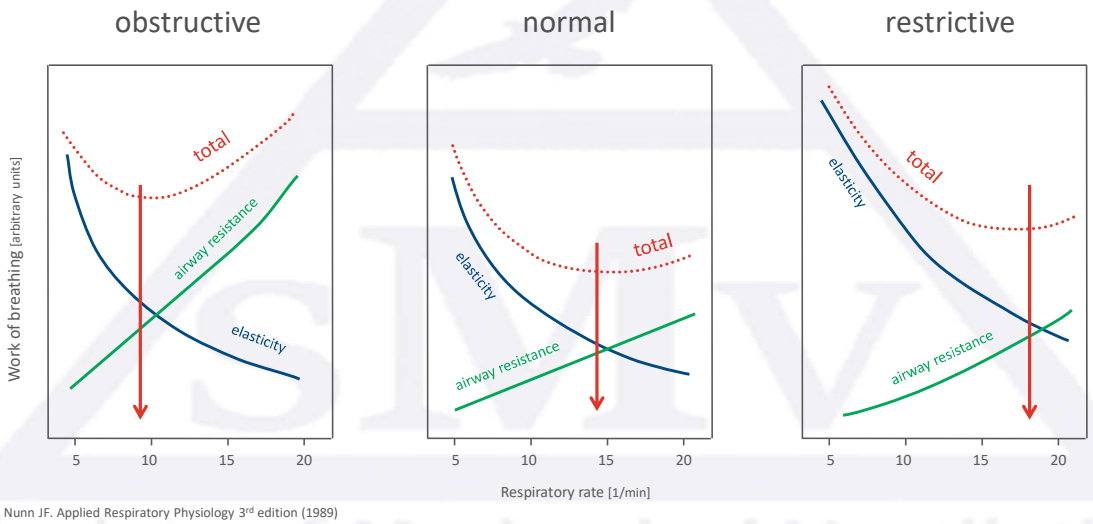
3

Adaptive modes names

- Adaptive Support Ventilation ASV 1.0
- Adaptive Support Ventilation ASV 1.1
- INTELLiVENT-ASV
- Adaptive Ventilation Mode AVM
- Adaptive Ventilation Mode AVM 2
- Work of Breathing Optimized Ventilation
- Adaptive Minute Ventilation

4

Respiratory rate change in predictable way . . .



Nunn JF. Applied Respiratory Physiology 3rd edition (1989)

5

Algorithms

Variables used to derive the cost functions

V_T = Tidal volume
P_T = Tidal pressure (Driving Pressure)
$f \cdot W_T$ = Tidal power (Driving Power)
$f \cdot W_{mus}$ = Breathing power (ASV)
P_{insp} = Inspiratory pressure (MFV)
$f \cdot W_T$ = Inspiratory power (AVM 2)

Required alveolar minute ventilation MV_A

Cost function

Minimize cost function (Analytically or simulation based)

Optimum ventilation frequency with smallest costs

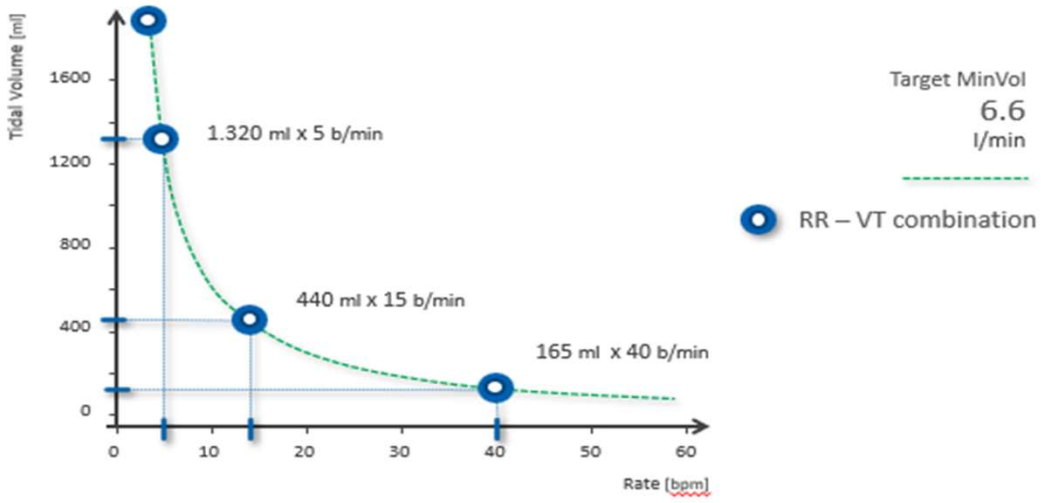
Targets

$V_A = MV_A/f$
$V_T = V_A + V_D$

van der Staay, M., Chatburn, R.L. Advanced modes of mechanical ventilation and optimal targeting schemes. ICMx 6, 30 (2018).

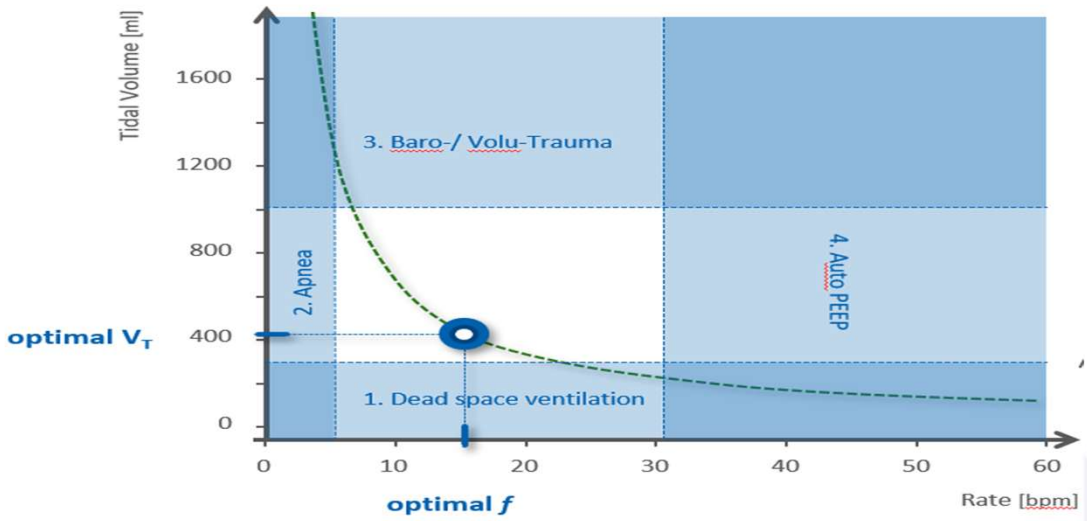
6

Algorithms



7

Algorithms



8

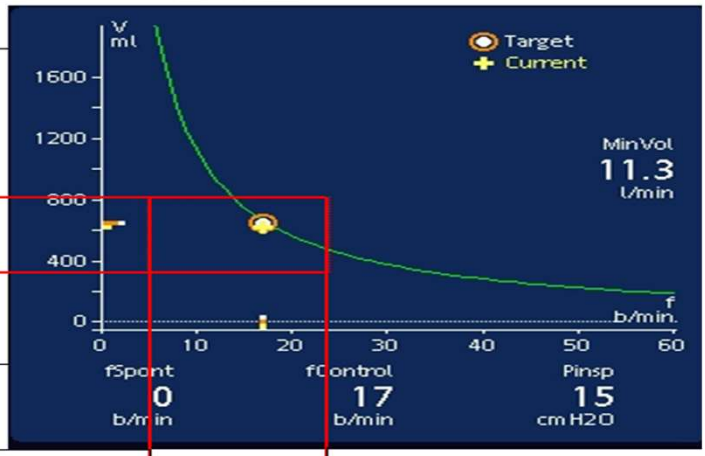
Algorithms

A – high tidal volumes and pressures

V_T max ≤ 10x V_D or (Ppeak – PEEP) x C_{dyn}

B – low alveolar ventilation

V_T min ≥ 2x V_D

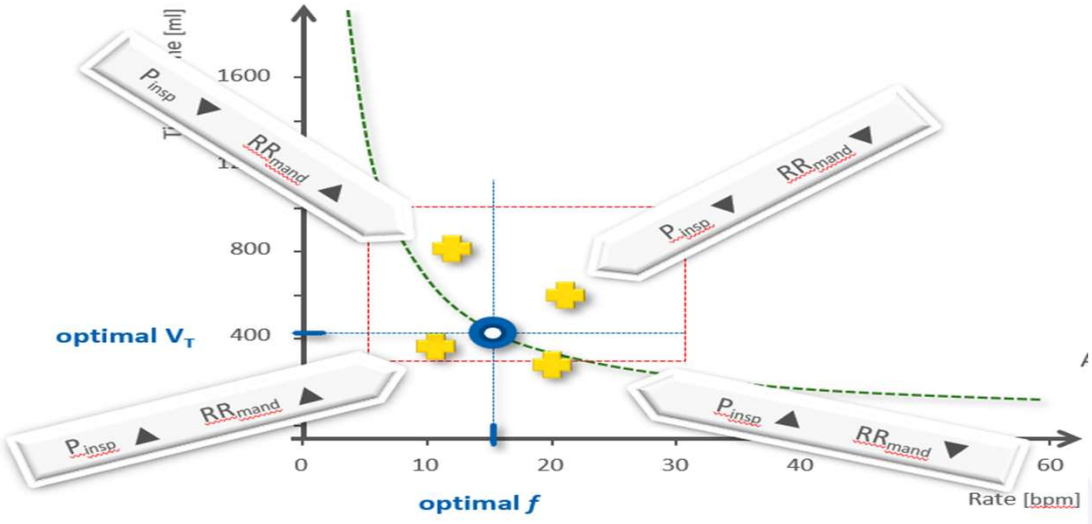


C – apnea
RR ≥ 5/min

D – dynamic hyperinflation
RR max ≤ 60/ 3x RCexp

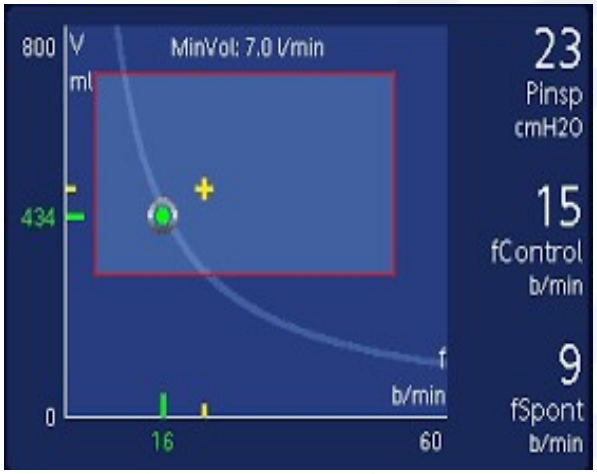
9

Algorithms



10

ASV (Breathing Power)



Otis

$$\underbrace{\dot{W}_{mus}}_{\text{Totalpower}} = \underbrace{\frac{f}{2 \cdot C} \cdot \left(\frac{MV_A}{f} + V_D\right)^2}_{\text{Tidalpower}} + \underbrace{\frac{1}{4} \cdot R \cdot \pi^2 \cdot (MV_A + f \cdot V_D)^2}_{\text{Resistivepower(viscous)}} + \underbrace{\frac{2}{3} \cdot R' \cdot \pi^2 \cdot (MV_A + f \cdot V_D)^3}_{\text{Resistivepower(turbulent)}}$$

Mead

$$f_{BP} = \frac{-1 + \sqrt{1 + \frac{4 \cdot \pi^2 \cdot RC \cdot MV_A}{V_D}}}{2 \cdot \pi^2 \cdot RC}$$

$$f_{BF} = \left(\frac{MV_A}{V_D}\right)^{1/3} \cdot (2\pi RC)^{-2/3}$$

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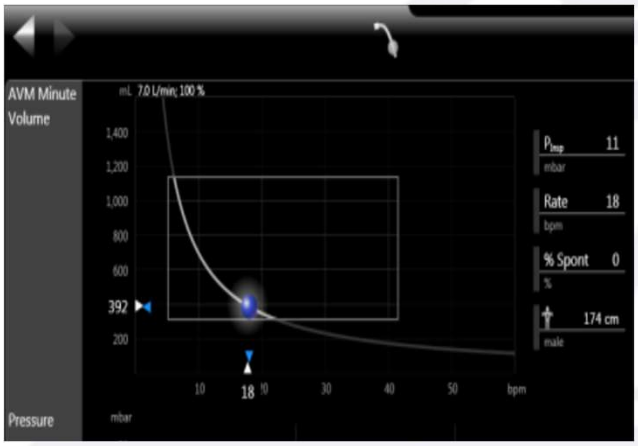
AVM (Inspiratory Power)

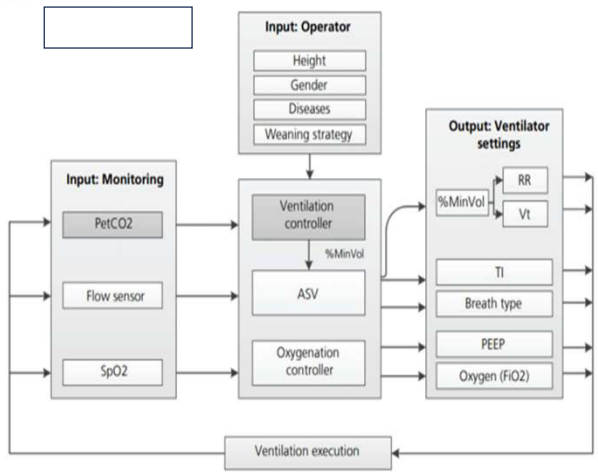


$$\dot{W}_{insp} = \frac{1}{2 \cdot C} \cdot f \cdot \left(\frac{MV_A}{f} + V_D\right)^2 \cdot \left(1 + \coth\left(\frac{T_I}{2 \cdot R \cdot C}\right)\right)$$

$$f_{IP} = \frac{MV}{2 \cdot V_D} \left(1 - \frac{1}{2 \cdot f_{IP} \cdot R \cdot C \cdot \left(e^{\frac{1}{2 \cdot f_{IP} \cdot R \cdot C}} - 1\right)}\right)$$

12

Automatic adjustment of FiO_2 and CO_2 Elimination



Arnal JM, Daoud EG. Guidelines on setting the target minute ventilation in Adaptive Support Ventilation. J Mech Vent 2021; 2(3):80-85.

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Settings

Clinician

- Gender & Height → IBW
- % Minute Ventilation (25%-350%): 100% = 100 ml/kg/min
- FiO_2
- PEEP
- Expiratory Sensitivity (for spontaneous breaths) or automatic cycling
- Rise time or automatic
- Target SPO_2 and $PECO_2$

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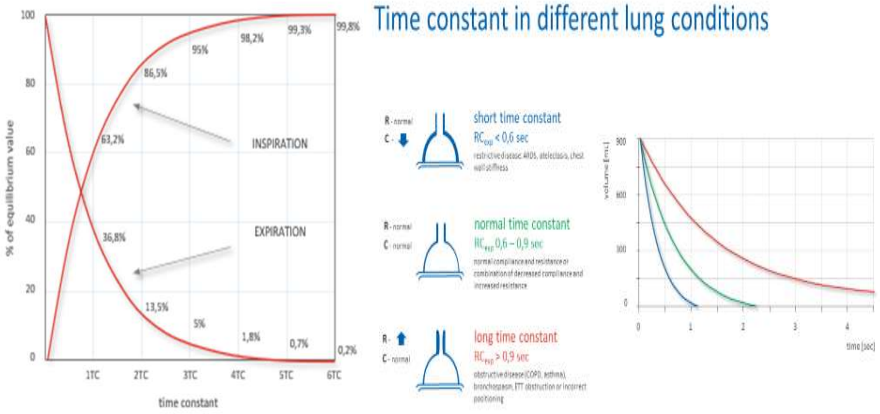
Settings

Ventilator

(Calculates Respiratory mechanics: Compliance, Resistance, Auto-PEEP)

(Expiratory Time Constant (Compliance x Resistance)

- Tidal Volume
- Respiratory Rate
- Inspiratory pressure
- I-Time & I:E ratio
- FiO_2 & PEEP



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Settings

Guidelines on setting the target minute ventilation in Adaptive Support Ventilation

Jean-Michel Arnal MD [1], Ehab Daoud MD [2]

Lung condition	Initial %MV setting*	Adjustment in passive patients	Adjustment step in passive patients	Adjustment in spontaneous breathing patients	Adjustment step in spontaneous breathing patients
Normal lung	100%	According to $PaCO_2$	± 10%	According to patient's effort and RR	± 20%
ARDS	130%				
COPD	130%				

* Clinician may add 10% in case of HME use.

Table 1: suggested initial settings of percent minute ventilation and their subsequent adjustment in three different clinical scenarios.

	50%	100%	150%	200%	250%	300%
Normal	430 (6.1 ml/kg)	513 (7.3 ML/KG)	580 (8.3 ML/KG)	638 (9.1 ml/kg)	689 (9.8 ml/kg)	736 (10.5 ml/kg)
ARDS	363 (5.2 ml/kg)	406 (5.8 ml/kg)	443 (6.3 ml/kg)	475 (6.78 ml/kg)	505 (7.2 ml/kg)	532 (7.6 ml/kg)
COPD	578 (8.2 ml/kg)	734 (10.5 ml/kg)	920 (13 ml/kg)	1170 (16.7 ml/kg)	1539 (21.9 ml/kg)	1539 (21.9 ml/kg)

Table 2: Target tidal volume and minute ventilation according to set %MV in three different clinical scenarios.

Arnal JM, Daoud EG. Guidelines on setting the target minute ventilation in Adaptive Support Ventilation. J Mech Vent 2021; 2(3):80-85.

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Weaning

- **Phase 1 – Screening**
  - If deep sedation is stopped and the patient is active, gradually reduce %MinVol (at most to 70% MinVol), PEEP, and Oxygen every hour.
- **Phase 2 - Observation**
  - If the patient's respiratory rate is < 30 breaths/min, Pinsp < 15 cmH_2O, PEEP ≤ 8 cmH_2O, Oxygen ≤ 40%, or according to your ICU standard for 30min to 2h, consider an SBT
- **Phase 3 - Spontaneous breathing trial (SBT)**
  - Suggested SBT settings:
    PEEP = 5-8 cmH_2O
    Oxygen = 30-40 %
    %MinVol = 25% for 30 minutes
- **Phase 4 – Extubation**

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Benefits and Evidence

- Lung protection and Mechanical Power
- Comparison against conventional modes of ventilation
- Weaning
- Automatic adjustments for Oxygenation
- Ventilator setting adjustments

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Reduction of Mechanical Power

RESEARCH ARTICLE | VOLUME 49, ISSUE 4, P427-434, JULY 2020 Download Full Issue

Airway and transpulmonary driving pressures and mechanical powers selected by INTELLiVENT-ASV in passive, mechanically ventilated ICU patients

Background

Driving pressure (ΔP) and mechanical power (MP) are predictors of the risk of ventilation- induced lung injuries (VILI) in mechanically ventilated patients. INTELLiVENT-ASV® is a closed-loop ventilation mode that automatically adjusts respiratory rate and tidal volume, according to the patient's respiratory mechanics.

Objectives

This prospective observational study investigated ΔP and MP (and also transpulmonary ΔP (ΔP_L) and MP (MP_L) for a subgroup of patients) delivered by INTELLiVENT-ASV.

Methods

Adult patients admitted to the ICU were included if they were sedated and met the criteria for a single lung condition (normal lungs, COPD, or ARDS). INTELLiVENT-ASV was used with default target settings. If PEEP was above 16 cmH2O, the recruitment strategy used transpulmonary pressure as a reference, and ΔP_L and MP_L were computed. Measurements were made once for each patient.

Results

Of the 255 patients included, 98 patients were classified as normal-lungs, 28 as COPD, and 129 as ARDS patients. The median ΔP was 8 (7 – 10), 10 (8 – 12), and 9 (8 – 11) cmH2O for normal-lungs, COPD, and ARDS patients, respectively. The median MP was 9.1 (4.9 – 13.5), 11.8 (8.6 – 16.5), and 8.8 (5.6 – 13.8) J/min for normal-lungs, COPD, and ARDS patients, respectively. For the 19 patients managed with transpulmonary pressure ΔP_L was 6 (4 – 7) cmH2O and MP_L was 3.6 (3.1 – 4.4) J/min.

Conclusions

In this short term observation study, INTELLiVENT-ASV selected ΔP and MP considered in safe ranges for lung protection. In a subgroup of ARDS patients, the combination of a recruitment strategy and INTELLiVENT-ASV resulted in an apparently safe ΔP_L and MP_L.

Arnal JM, et al. Airway and transpulmonary driving pressures and mechanical powers selected by INTELLiVENT-ASV in passive, mechanically ventilated ICU patients. Heart Lung. 2020;49(4):427-434.

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Reduction of Mechanical Power

Comparison of Mechanical Power During Adaptive Support Ventilation Versus Nonautomated Pressure-Controlled Ventilation—A Pilot Study

OBJECTIVES: The aim of this pilot study was to compare the amount of "mechanical power of ventilation" under adaptive support ventilation with nonautomated pressure-controlled ventilation.

DESIGN: Single-center, observational prospective pilot study adjoining unitwide implementation of adaptive support ventilation in our department.

SETTING: The ICU of a nonacademic teaching hospital in the Netherlands.

PATIENTS: Twenty-four passive invasively ventilated critically ill patients expected to need of invasive ventilation beyond the following calendar day.

MEASUREMENTS AND MAIN RESULTS: In patients under adaptive support ventilation, only positive end-expiratory pressure and Fio_2 were set by the caregivers—all other ventilator settings were under control of the ventilator; in patients under pressure-controlled ventilation, maximum airway pressure (Pmax), positive end-expiratory pressure, Fio_2, and respiratory rate were set by the caregivers. Mechanical power of ventilation was calculated three times per day. Compared with pressure-controlled ventilation, mechanical power of ventilation with adaptive support ventilation was lower (15.1 [10.5–25.7] vs 22.9 [18.7–28.8] J/min; $p = 0.04$). Tidal volume was not different, but Pmax ($p = 0.012$) and respiratory rate ($p = 0.012$) were lower with adaptive support ventilation.

CONCLUSIONS: This study suggests adaptive support ventilation may have benefits compared with pressure-controlled ventilation with respect to the mechanical power of ventilation transferred from the ventilator to the respiratory system in passive invasively ventilated critically ill patients. The difference in mechanical power of ventilation is not a result of a difference in tidal volume, but the reduction in applied pressures and respiratory rate. The findings of this observational pilot study need to be confirmed in a larger, preferably randomized clinical trial.

KEY WORDS: closed-loop ventilation; critical care medicine; mechanical power; mechanical ventilation

Buiteman-Kruizinga LA, et al. Comparison of Mechanical Power During Adaptive Support Ventilation Versus Nonautomated Pressure-Controlled Ventilation-A Pilot Study. Crit Care Explor. 2021;3(2):e0335.

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Reduction of Mechanical Power

Mechanical power in AVM-2 versus conventional ventilation modes in a normal lung model: A bench study

Parthav Shah, [1] Jihun Yeo, [1] Witina Techasatian, [1] Claudio Luciano Franck, [2] Ehab Daoud [3]

DOI: https://doi.org/10.53097/JMV.10047

Cite: Shah P, Yeo J, Techasatian W, Franck CL, Daoud EG. Mechanical power in AVM-2 versus conventional ventilation modes in a normal lung model: A bench study. J Mech Vent 2022; 3(2):45-53.

Abstract

Introduction
Recent studies suggested that the energy delivered by the mechanical ventilator to the lungs termed the mechanical power can induce and increase the risks of ventilator induced lung injury. The components of the mechanical power include the variables delivered by the ventilator: tidal volume, respiratory rate, inspiratory flow, airway pressure. Adaptive Ventilator Mode-2 (AVM-2) is a pressure-controlled mode with an optimal targeting scheme based on the inspiratory power equation that adjusts the respiratory rate and tidal volume to achieve a target minute ventilation. This mode conceptually should reduce the mechanical power delivered to the patients and thus reduce the incidence of ventilator induced lung injury.

Methodology
A bench study using a lung simulator (TTL, Michigan Instruments, Michigan, USA) was conducted. We constructed a passive single compartment normal respiratory mechanics model with compliance of 50 ml/cmH_2O, and resistance of 10 cmH_2O/L/s, with IBW 70 kg. We compared three different ventilator modes: Adaptive Ventilation Mode-2 (AVM-2), Pressure Regulated Volume Control (PRVC), and Volume Controlled Ventilation (VCV) in four different scenarios: 2 levels of minute ventilation 7 and 10.5 Lit/min (Experiment 1 and 2 respectively), each with 2 different PEEP levels 5 and 10 cmH_2O (Experiment A and B respectively) termed Experiments 1A, 1B, 2A, and 2B respectively.
The AVM-2 mode automatically selects the optimal tidal volume, and respiratory rate per the dialed percent minute ventilation with an I:E ratio of 1:1. In the PRVC, VCV we selected target tidal volume 6ml/kg/IBW (420 ml), and respiratory rate adjusted to match the minute ventilation for the AVM-2 mode. I:E ratio was kept 1:2 to avoid intrinsic PEEP. The study was conducted using a bellavista™ 1000 e Ventilator (Vyaire Medical, Illinois, USA).
The mechanical power delivered by the ventilator for each mode was computed and compared between the three modes in each experiment. Statistical analysis was done using Kruskal-Wallis test to analyze the difference between the three modes, post HOC Tukey test was used to analyze the difference between each mode with the confidence intervals, $P < 0.05$ was considered statistically significant.

Results
There were statistically significant differences between all the three modes regarding the ventilator delivered mechanical power. The AVM-2 mode delivered significantly less mechanical power than VCV which in turn was less than PRVC. Experiment 1A: AVM-2 8.76 ± 0.05, VCV 9.78 ± 0.04, PRVC 10.82 ± 0.08, $P < 0.001$ Experiment 1B: AVM-2 11.27 ± 0.09 VCV 12.81 ± 0.05, PRVC 13.88 ± 0.06, $P < 0.001$. Experiment 2A: AVM-2 14.76 ± 0.05, VCV 15.79 ± 0.05, PRVC 18.29 ± 0.07, $P < 0.001$, Experiment 2B: AVM-2 18.76 ± 0.04, VCV 20.56 ± 0.04, PRVC 21.17 ± 0.03, $P < 0.001$.

Discussion
AVM2 mode delivered less mechanical power compared to two conventional modes using low tidal volume in a normal lung model. This might reduce the incidence of ventilator induced lung injury. Results need to be validated in more clinical studies.

Keywords: AVM-2, Mechanical power, VILI

Shah P, et al. Mechanical power in AVM-2 versus conventional ventilation modes in a normal lung model: A bench study. J Mech Vent 2022; 3(2):45-54.

Mechanical power in AVM-2 versus conventional ventilation modes in various ARDS lung models. Bench study

Jihun Yeo, [1] Parthav Shah, [1] Keitoku Koichi, [1] Maan Gozun, [1] Claudio Luciano Franck, [2] Ehab G. Daoud [3]

DOI: https://doi.org/10.53097/JMV.10056

Cite: Yeo J, Shah P, Koichi K, Franck CL, Daoud EG. Mechanical power in AVM-2 versus conventional ventilation modes in in various ARDS lung models: A bench study. J Mech Vent 2022; 3(3):110-122.

Abstract

Introduction
Mechanical power has been linked to ventilator induced lung injury and mortality in acute respiratory distress syndrome (ARDS). Adaptive Ventilator Mode-2 (AVM-2) is a closed-loop pressure-controlled mode with an optimal targeting scheme based on the inspiratory power equation that adjusts the respiratory rate and tidal volume to achieve a target minute ventilation. Conceptually, this mode should reduce the mechanical power delivered to the patients and thus reduce the incidence of ventilator induced lung injury.

Methods
A bench study using a lung simulator was conducted. We constructed three passive single compartment ARDS models (Mild, Moderate, Severe) with compliance of 40, 30, 20 ml/cmH_2O respectively, and resistance of 10 cmH_2O/L/s, with IBW 70 kg. We compared three different ventilator modes: AVM-2, Pressure Regulated Volume Control (PRVC), and Volume Controlled Ventilation (VCV) in six different scenarios: 3 levels of minute ventilation 7, 10.5, and 14 Lit/min (Experiment 1, 2, and 3 respectively), each with 3 different PEEP levels 10, 15, and 20 cmH_2O (Experiment A, B, and C respectively) termed 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 3C respectively for a total of 81 experiments.
The AVM-2 mode automatically selects the optimal tidal volume and respiratory rate per the dialed percent minute ventilation with an I:E ratio of 1:1. In the PRVC and VCV (constant flow) we selected target tidal volume 6ml/kg/IBW (420 ml) and respiratory rate adjusted to match the minute ventilation for the AVM-2 mode. I:E ratio was kept 1:2.
The mechanical power delivered by the ventilator for each mode was computed and compared between the three modes in each experiment. Statistical analysis was done using Kruskal-Wallis test to analyze the difference between the three modes, post HOC Tukey test was used to analyze the difference between each mode where $P < 0.05$ was considered statistically significant. The Power Compliance Index was calculated and compared in each experiment. Multiple regression analysis was performed in each mode to test the correlation of the variables of mechanical power to the total calculated power.

Results
There were statistically significant differences ($P < 0.001$) between all the three modes regarding the ventilator delivered mechanical power. AVM-2 mode delivered significantly less mechanical power than VCV which in turn was less than PRVC. The Power Compliance index was also significantly lower ($P < 0.01$) in the AVM-2 mode compared to the other conventional modes. Multiple regression analysis indicated that in AVM-2 mode, the driving pressure ($P = 0.004$), tidal volume ($P < 0.001$), respiratory rate (P 0.011) and PEEP ($P < 0.001$) were significant predictors in the model. In the VCV mode, the respiratory rate ($P < 0.001$) and PEEP ($P < 0.001$) were significant predictors, but the driving pressure was a non-significant predictor (P 0.08). In PRVC mode, the respiratory rate ($P < 0.001$), PEEP ($P < 0.001$) and driving pressure ($P < 0.001$) were significant predictors.
Conclusion
AVM-2 mode delivered less mechanical power compared to two conventional modes using low tidal volume in an ARDS lung model with different severities. This might translate to the reduction of the incidence of ventilator induced lung injury. Results need to be validated in clinical studies.

Keywords: Mechanical power, Power Compliance Index, AVM-2

Yeo J, et al. Mechanical power in AVM-2 versus conventional ventilation modes in in various ARDS lung models: A bench study. J Mech Vent 2022; 3(3):110-122.

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Reduction of Mechanical Power

Article

Effect of INTELLiVENT-ASV versus Conventional Ventilation on Ventilation Intensity in Patients with COVID-19 ARDS—An Observational Study

Abstract: Driving pressure (ΔP) and mechanical power (MP) are associated with outcomes in critically ill patients, irrespective of the presence of Acute Respiratory Distress Syndrome (ARDS). INTELLiVENT-ASV, a fully automated ventilatory mode, controls the settings that affect ΔP and MP. This study compared the intensity of ventilation (ΔP and MP) with INTELLiVENT-ASV versus conventional ventilation in a cohort of COVID-19 ARDS patients in two intensive care units in the Netherlands. The coprimary endpoints were ΔP and MP before and after converting from conventional ventilation to INTELLiVENT-ASV. Compared to conventional ventilation, INTELLiVENT-ASV delivered ventilation with a lower ΔP and less MP. With conventional ventilation, ΔP was 13 cmH_2O, and MP was 21.5 and 24.8 J/min, whereas with INTELLiVENT-ASV, ΔP was 11 and 10 cmH_2O (mean difference −2 cm H2O (95 %CI −2.5 to −1.2 cm H_2O), $p < 0.001$) and MP was 18.8 and 17.5 J/min (mean difference −7.3 J/Min (95% CI −8.8 to −5.8 J/min), $p < 0.001$). Conversion from conventional ventilation to INTELLiVENT-ASV resulted in a lower intensity of ventilation. These findings may favor the use of INTELLiVENT-ASV in COVID-19 ARDS patients, but future studies remain needed to see if the reduction in the intensity of ventilation translates into clinical benefits.

Keywords: COVID-19; ARDS; automated ventilation; closed-loop ventilation; INTELLiVENT-ASV; intensity of ventilation; mechanical power; driving pressure

Buiteman-Kruizinga LA, et al. Effect of INTELLiVENT-ASV versus Conventional Ventilation on Ventilation Intensity in Patients with COVID-19 ARDS—An Observational Study. Journal of Clinical Medicine. 2021; 10(22):5409.

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Comparison to conventional modes

Study	Study Design	Objectives	Results	Conclusion
Kirakli C, et al (2015)	Randomized controlled trial of 229 patients in a medical ICU.	ASV compared to PCV in regard to duration of time on the ventilator.	ASV group resulted with a shorter mechanical ventilation duration until weaning (67 hours vs 92 hours, P = 0.003); shorter weaning duration (2 [2-2] h vs 2 [2-80] h, P = 0.001); and shorter total mechanical ventilation duration (4 days vs 4 [3-9] days, P = 0.016) in comparison to PCV. ASV also required fewer manual ventilator changes than PCV (2 vs 3, P <. 0.001). The ASV group also had a higher number of patients who were successfully extubated on the first attempt in comparison to PCV, with weaning success and mortality being similar at day 28.	ASV can shorten the duration of weaning and total duration of mechanical ventilation in medical ICU patients and may require fewer manual ventilator changes.
Agarwal R, et al (2013)	Pilot, randomized controlled trial of 48 patients with ARDS.	Compare outcomes of ASV to volume cycled ventilation in patients with ARDS.	The ASV and VCV groups showed no significant differences in the following end points: duration of mechanical ventilation, ICU and hospital length of stay, mortality, ease of use of mechanical ventilation mode, daily doses of sedation and neuromuscular blockers, and number of ABG samples.	No significant difference in outcomes between ASV and VCV and mechanical ventilation of patients with ARDS
Dongelmans D (2011)	Prospective observational study of 10 patients during mechanical ventilation with a change to ASV from PCV.	Compare respiratory rates and tidal volume delivery in ASV to PCV in an open lung ventilator strategy in patients with acute lung injury.	ASV resulted in a decline of respiratory rate than with PCV (31±5 to 21±6 breaths/min, P = 0.008), and an increase in tidal volume (6.5 ±0 .8 to 9.0 ± 1.6 mL/kg predicted body weight, P = 0.02) when compared to PCV. Pressure limitation corrected for tidal volume rise of > 8 mL/kg but there was a decline in minute ventilation and PCV was resumed.	ASV will deliver a low respiratory rate and high tidal volume during open lung ventilator strategy. Pressure limitations can be used to correct for the rise of tidal volume but will decline minute ventilation.
Iotti G, et al (2010)	Prospective crossover interventional multicenter trial of 88 patients passively ventilated for acute respiratory failure with varying lung conditions: none, restrictive, and obstructive.	Compare ASV to conventional ventilation (VCV or PCV) regarding short term effects.	ASV and conventional ventilation remained unchanged in oxygenation and hemodynamics. In obstructed patients, ASV provided slightly higher tidal volumes and slightly lower respiratory rates. In patients with restrictive lung disease, ASV provided lower tidal volumes. These changes were similar to the settings that were chosen by clinicians during conventional ventilation.	ASV and conventional ventilation resulted in similar or minor differences. All differences were in favor of ASV, except for excessive tidal volumes delivered to patients with obstructed lung disease.

Wheatley D, Young, K. Adaptive support ventilation. What is it? Beneficial or not? J Mech Vent 2020; 2(1):34-44.

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Comparison to conventional modes

Ghodrati M, et al (2016).	Crossover study of sixty patients in a neurosurgical ICU.	Compare ASV to SIMV regarding respiratory parameters (tidal volume, respiratory rate, airway pressure, lung compliance, end-tidal carbon dioxide, peripheral oxygenation, and respiratory dead space) differences in neurosurgical ICU patients. Patients were placed on both ASV and SIMV modes for 30 minutes duration.	Peak airway pressures, end-tidal carbon dioxide, tidal volumes and respiratory dead space values that were significantly lower with ASV than SIMV. Lung compliance showed no significant difference between ASV and SIMV modes but was slightly improved with ASV.	AS may lead to improved lung compliance and respiratory dead space compared to SIMV.
El-Shenawy O et al (2018)	Randomized controlled trial of 60 patients with COPD.	Compare benefits of ASV to SIMV with PS regarding initiation, maintenance, and weaning of mechanical ventilation in patients with acute exacerbation of COPD.	ASV resulted with shorter weaning times than SIMV with PS (27.3 ± 12.3 vs 62 ± 14.1 h). ASV also resulted in a shorter length of hospital stay (14.83 ± 6.14 vs 22.14 ± 17.39 days). Weaning failure rates, mortality, and intubation duration showed no significant difference between ASV and SIMV with PS.	ASV is successful for initiation, maintenance, and weaning in COPD patients providing shorter weaning times and length of hospital stay.
Sehgal I, et al (2019)	Feasibility trial. Exploratory study of 74 patients with acute exacerbation of COPD.	Compare Non-Invasive Ventilation (NIV) with ASV to NIV with PSV for patients with acute exacerbation of COPD regarding NIV failure and duration of mechanical ventilation.	NIV failure rate was similar in both ASV and PSV (22.2% vs 34.2%, P = 0.31). NIV with ASV resulted in a 9% reduction in intubation rate than NIV with PSV. Mortality with ASV vs PSV (4 vs 2). There was no significant difference in duration of mechanical ventilation between NIV with ASV or NIV with PSV.	NIV with ASV showed no significant difference than NIV with PSV for patients with an acute exacerbation of COPD.
Dai Y et al (2019)	Randomized clinical trial of 15 ARDS patients. Study also included an animal experiment of 18 piglets.	Research to determine if ASV could provide a protective ventilation pattern to minimize the risk of ventilator-induced lung injury in patients with ARDS in comparison to VCV.	In the human study of patients with ARDS, there was no significant difference in respiratory parameters and mortality with ASV and VCV. In the animal experiment, ASV resulted in lower alveolar strain and greater alveolar fluid clearance compares to VCV.	ASV can provide ventilatory patterns that provide lung protective strategies. ASV may reduce the risk/severity of ventilator-associated lung injury in animal models.
Jung B, et al (2010)	In vivo and in vitro animal study of 12 anesthetized piglets over 72 hours.	Compare ASV with conventional mechanical ventilation on in vivo and in vitro diaphragmatic properties.	There was no decrease in transdiaphragmatic pressure with the piglets mechanically ventilated with ASV, there was a 30% decrease in the conventional mechanical group.	ASV may help to maintain diaphragmatic contractile activity and protect the diaphragm against deleterious effects of prolonged conventional mechanical ventilation.
Sulemanji D, et al (2009)	Bench study with a lung simulator in ARDS model.	Compare respiratory pattern with ASV to VCV in ARDS model with tidal volume, without exceeding plateau pressure of 28 cm H2O.	ASV maintained a lower plateau pressure than the fixed tidal volume in the low lung compliance, increased PEEP, and increased target minute volume scenarios.	ASV decreases tidal volume to maintain a safe plateau pressure.

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PCV vs AVM mode clinical trial

- Prelim data comparing 2 hours PCV to AVM mode using same minute ventilation
- Pilot study, not peer reviewed or published yet
- Data on 22 patients with different diseases
- MP (PCV): 23.17 ± 7.2
- MP (AVM): 17.44 ± 3.5

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Weaning

Zhu F, et al (2015)	Randomized, parallel arm, unblinded trial of 68 patients, post-operative cardiac valvular patients over a three-month period.	Comparison of duration of mechanical ventilation with ASV to physician-directed weaning after adult fast-track cardiac valvular surgery.	ASV group resulted with a shorter duration of mechanical ventilation in comparison to physician-directed weaning 205 minutes vs 342 minutes, P = 0.013. ASV also resulted in less alarms and manual ventilator changes, but ABG samples were more common.	ASV resulted in a reduced amount of mechanical ventilation duration by more than 2 hours for post-operative fast-track cardiac valvular surgery patients.
Aghadavoudi O, et al (2012)	Randomized clinical trial of 100 patients, post-operative CABG with cardiopulmonary bypass over a four month period.	Assess and compare risks and benefits of respiratory weaning with ASV to SIMV after CABG surgery	There was no significant difference in the length of intubation and mechanical ventilation between ASV and SIMV groups (498.7±185.3 minutes vs 469.3±141 minutes, P = 0.8). There was no significant difference in the length of hospital stay between ASV and SIMV groups 27 ± 3.4 h vs 26.2 ± 2.4 h, P = 0.4)	Both ASV and SIMV provide safe and practicable weaning for post-operative CABG surgery.
Yazdannik A, et al (2016)	Randomized controlled trial of 64 patients, post-operative CABG surgery.	Compare effects of ASV to effects of SIMV on length of mechanical ventilation and hospital stay after CABG surgery.	ASV group resulted in a shorter mechanical ventilation time in comparison to the SIMV group (4.83 h vs 6.71 h, P < 0.001). ASV group resulted in a shorter length of hospital stay (140.6 h vs 145.1 h, P = 0.006)	ASV decreased mechanical ventilation duration and hospital stay.
Tam MK, et al (2016)	Randomized controlled unblinded study of 52 patients, post-operative CABG surgery.	Compare effectiveness of weaning for post-operative CABG surgery patients using ASV with decremental target minute ventilation compared to protocol with a constant target minute ventilation.	ASV with decremental target minute ventilation resulted in a reduced duration of time intubated (225 vs 423 minutes, P = 0.005) and time of mechanical ventilation in comparison to protocol with constant target minute ventilation (145 vs 309 minutes, P = 0.001). The two groups showed no significant differences in adverse effects (42% vs 46%) and mortality (0% vs 0%).	ASV with decremental target minute ventilation reduced the time on mechanical ventilation without increase of adverse effects or mortality.
Lellouche F, et al (2013)	Randomized controlled study of 60 patients, post-operative cardiac surgery.	Evaluate the safety of automated ventilation in comparison to protocolized ventilation for post-operative cardiac surgery patients.	The automated ventilation group resulted with a higher percentage of time in optimal ventilation (89.5% vs 12%), and lower percentage of time in acceptable (10% vs 81%) and not acceptable (0.5% vs 7%) ventilation when compared to protocolized ventilation (P < 0.001). Automated ventilation also resulted in less interventions than protocolized ventilation (5 vs 148 events).	Automated ventilation was safe for post-operative cardiac surgery patients providing an increased duration in optimal ventilation and reduced the number of interventions.

Wheatley D, Young, K. Adaptive support ventilation. What is it? Beneficial or not? J Mech Vent 2020; 2(1):34-44.

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Weaning

Gruber PC, et al (2008)	Randomized controlled trial of 50 patients, post-operative CABG surgery.	Compare ASV to PRVC with automode to determine if ASV results in a shorter time to extubation for post-operative CABG surgery patients.	ASV group resulted with a shorter intubation duration in comparison to PRVC with automode 300 minutes vs 540 minutes, P < 0.05). No significant differences were noted in the number of ABG samples or manual ventilator changes made between ASV and PRVC with automode.	ASV is associated with earlier extubation, with no significant differences in clinician intervention when compared to PRVC with automode.
Fathi HM, et al (2018)	Randomized controlled trial of 90 COPD patients, post-operative CABG surgery.	Compare ASV and PSV mode as a weaning mode for COPD patients in post-operative CABG surgery.	ASV group resulted with higher number of patients being weaned at first trial (26 vs 15, P < 0.034); shorter duration of: mechanical ventilation (56 ± 5 h vs 73 ± 6 h, P < 0.0001), weaning (32 ± 4 h vs 47 ±6 h, P < 0.0001), and ICU stay (7 ± 2 days vs 8 ± 1.9 days, P 0.017); fewer: manual ventilator adjustments (3 ± 1 vs 5 ± 1, P < 0.0001), ABG drawings (3 ± 1 vs 6 ± 1, P < 0.0001). At extubation patients in the ASV group displayed lower: respiratory rate (25 ± 4 vs 27 ± 3.8, P 0.017), peak inspiratory pressures (27.2 ± 3 cm H_2O vs 31 ± 4 cm H_2O, P < 0.0001); and higher tidal volumes (425 ± 40 mL vs 393 ±3 8 mL, P 0.0002)	ASV improved the quality of weaning and shortened ICU stay in COPD patients post CABG surgery, in comparison with PSV.
De Bie AJ, et al (2020)	Single-centre investigator-led randomized study of 220 patients, post cardiac surgery.	Compare ASV and conventional ventilation as a weaning mode for post-operative cardiac surgery patients determined by optimal, acceptable, and critical parameters, and severe hypoxaemia.	ASV patients received a higher number of optimal postoperative ventilation time (29.7% [95% CI: 22.1-37.4], P < 0.001); reduced postoperative ventilation time exposed to injurious ventilator settings (2.5% [95% CI: 1-4], P 0.003); and reduced risk for severe hypoxaemia (0.25 [0.22-0.31], P < 0.01) in comparison to conventional ventilation.	ASV optimized lung-protective ventilation during post-operative cardiac surgery, allowed for fewer episodes of severe hypoxaemia.
Kirakli C, et al (2011)	Randomized controlled trial of 97 patients with COPD over a 20-month period.	Compare ASV to PSV in reducing the weaning duration in patients with COPD.	ASV group resulted with a shorter weaning duration in comparison to PSV (24 h [20-62] vs 72 h (24-144), P = 0.041). Both ASV and PSV modes resulted in similar weaning success (35/49 vs 33/48).	ASV used as a weaning mode for COPD results in shorter weaning times. Differences in weaning success rates and length of stay in the ICU showed no significant difference.
Celli P, et al (2014)	Randomized controlled study with 20 post-operative liver transplant patients.	Compare ASV to SIMV with PS in post-operative liver transplantation patients.	ASV resulted in a shorter duration of intubation in comparison to SIMV with PS (90±13 vs 153±22 minutes P = 0.05). ASV also resulted in fewer ventilator changes in comparison to SIMV with PS (1.5±1 vs 6±2, P 0.003).	ASV proved to be superior regarding shorter weaning times. The results showed that both ASV and SIMV with PSV were safe.

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Automatic Oxygen Adjustment

Winck JC. Intelligent oxygen delivery in the acute setting: 'Don't think twice, it's all right'. Eur Respir J 2017; 50:1701013.

Katayama S, Shima J, Tonai K, et al. Accuracy of two pulse-oximetry measurementsfor INTELLiVENT-ASV in mechanically ventilated patients: a prospective observational study. Sci Rep 2021; 11:9001.

L'Her E, et al. Automatic versus manual oxygen administration in the emergency department. Eur Respir J 2017; 50:1602552.

Ouanes I, Bouhaouala F, Maatouk S, et al. Automatic oxygen administration and weaning in patients following mechanical ventilation. J Crit Care 2021;61:45–51.

Bialais E, et al. Closed-loop ventilation mode (IntelliVent®-ASV) in intensive care unit: a randomized trial. Minerva Anestesiol. 2016 Jun;82(6):657-68.

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Ventilator setting adjustments

Closed loop ventilation mode in Intensive Care Unit: a randomized controlled clinical trial comparing the numbers of manual ventilator setting changes

ABSTRACT

BACKGROUND: There is an equipoise regarding closed-loop ventilation modes and the ability to reduce workload for providers. On one hand some settings are managed by the ventilator but on another hand the automatic mode introduces new settings for the user.

METHODS: This randomized controlled trial compared the number of manual ventilator setting changes between a full closed loop ventilation and oxygenation mode (INTELLiVENT-ASV®) and conventional ventilation modes (volume assist control and pressure support) in Intensive Care Unit (ICU) patients. The secondary endpoints were to compare the number of arterial blood gas analysis, the sedation dose and the user acceptance.

Sixty subjects with an expected duration of mechanical ventilation of at least 48 hours were randomized to be ventilated using INTELLiVENT-ASV® or conventional modes with a protocolized weaning. All manual ventilator setting changes were recorded continuously from inclusion to successful extubation or death. Arterial blood gases were performed upon decision of the clinician in charge. User acceptance score was assessed for nurses and physicians once daily using a Likert Scale.

RESULTS: The number of manual ventilator setting changes per 24 h-period per subject was lower in INTELLiVENT-ASV® as compared to conventional ventilation group (5 [4-7] *versus* 10 [7-17]) manuals settings per subject per day [P<0.001]). The number of arterial blood gas analysis and the sedation doses were not significantly different between the groups. Nurses and physicians reported that INTELLiVENT-ASV® was significantly easier to use as compared to conventional ventilation (P<0.001 for nurses and P<0.01 for physicians).

CONCLUSIONS: For mechanically ventilated ICU patients, INTELLiVENT-ASV® significantly reduces the number of manual ventilator setting changes with the same number of arterial blood gas analysis and sedation dose, and is easier to use for the caregivers as compared to conventional ventilation modes.

Arnal JM. Closed loop ventilation mode in Intensive Care Unit: a randomized controlled clinical trial comparing the numbers of manual ventilator setting changes. Minerva Anestesiol. 2018 Jan;84(1):58-67.

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Ventilator setting adjustments

Closed-loop ventilation mode (IntelliVent®-ASV) in intensive care unit: a randomized trial

ABSTRACT

BACKGROUND: Closed-loop modes automatically adjust ventilation settings, delivering individualized ventilation over short periods of time. The objective of this randomized controlled trial was to compare safety, efficacy and workload for the health care team between IntelliVent®-ASV and conventional modes over a 48-hour period.

METHODS: ICU patients admitted with an expected duration of mechanical ventilation of more than 48 hours were randomized to IntelliVent®-ASV or conventional ventilation modes. All ventilation parameters were recorded breath-by-breath. The number of manual adjustments assesses workload for the healthcare team. Safety and efficacy were assessed by calculating the time spent within previously defined ranges of non-optimal and optimal ventilation, respectively.

RESULTS: Eighty patients were analyzed. The median values of ventilation parameters over 48 hours were similar in both groups except for PEEP (7[4] cmH_2O *versus* 6[3] cmH_2O with IntelliVent®-ASV and conventional ventilation, respectively, P=0.028) and $P_{ET}CO_2$ (36±7 mmHg with IntelliVent®-ASV *versus* 40±8 mmHg with conventional ventilation, P=0.041). Safety was similar between IntelliVent®-ASV and conventional ventilation for all parameters except for P_{MAX}, which was more often non-optimal with IntelliVent®-ASV (P=0.001). Efficacy was comparable between the 2 ventilation strategies, except for SpO_2 and V_T, which were more often optimal with IntelliVent®-ASV (P=0.005, P=0.016, respectively). IntelliVent®-ASV required less manual adjustments than conventional ventilation (P<0.001) for a higher total number of adjustments (P<0.001). The coefficient of variation over 48 hours was larger with IntelliVent®-ASV in regard of maximum pressure, inspiratory pressure (P_{INSP}), and PEEP as compared to conventional ventilation.

CONCLUSIONS: IntelliVent®-ASV required less manual intervention and delivered more variable PEEP and P_{INSP}, while delivering ventilation safe and effective ventilation in terms of V_T, RR, SpO_2 and $P_{ET}CO_2$.

Bialais E, et al. Closed-loop ventilation mode (IntelliVent®-ASV) in intensive care unit: a randomized trial. Minerva Anestesiol. 2016 Jun;82(6):657-68

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Ventilator setting adjustments

Closed-loop oxygen control improves oxygen therapy in acute hypoxemic respiratory failure patients under high flow nasal oxygen: a randomized cross-over study (the HILOOP study)

Abstract

Background: We aimed to assess the efficacy of a closed-loop oxygen control in critically ill patients with moderate to severe acute hypoxemic respiratory failure (AHRF) treated with high flow nasal oxygen (HFNO).

Methods: In this single-centre, single-blinded, randomized crossover study, adult patients with moderate to severe AHRF who were treated with HFNO (flow rate ≥ 40 L/min with $FiO_2 \geq 0.30$) were randomly assigned to start with a 4-h period of closed-loop oxygen control or 4-h period of manual oxygen titration, after which each patient was switched to the alternate therapy. The primary outcome was the percentage of time spent in the individualized optimal SpO_2 range.

Results: Forty-five patients were included. Patients spent more time in the optimal SpO_2 range with closed-loop oxygen control compared with manual titrations of oxygen (96.5 [93.5 to 98.9] % vs. 89 [77.4 to 95.9] %; $p < 0.0001$) (difference estimate, 10.4 (95% confidence interval 5.2 to 17.2). Patients spent less time in the suboptimal range during closed-loop oxygen control, both above and below the cut-offs of the optimal SpO_2 range, and less time above the suboptimal range. Fewer number of manual adjustments per hour were needed with closed-loop oxygen control. The number of events of $SpO_2 < 88\%$ and $< 85\%$ were not significantly different between groups.

Conclusions: Closed-loop oxygen control improves oxygen administration in patients with moderate-to-severe AHRF treated with HFNO, increasing the percentage of time in the optimal oxygenation range and decreasing the workload of healthcare personnel. These results are especially relevant in a context of limited oxygen supply and high medical demand, such as the COVID-19 pandemic.

Roca O, et al. Closed-loop oxygen control improves oxygen therapy in acute hypoxemic respiratory failure patients under high flow nasal oxygen: a randomized cross-over study (the HILOOP study). Crit Care. 2022 Apr 14;26(1):108.

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Conclusion

- Closed-loop ventilation modes automatically adjust certain ventilator settings to keep physiological variables within target ranges.
- The time spent in optimal SpO2 target ranges is increased, preventing both hypoxemia and hyperoxemia.
- VT, DP, and MP are kept within the recommended lung protection ranges.
- ***Studies demonstrate the potential of closed-loop systems to reduce the duration of weaning and mechanical ventilation, no clear evidence that these physiological benefits improve important clinical outcomes***
- Large, multicenter, randomized controlled trials are needed to assess the impact on important clinical outcomes and cost effectiveness

Arnal JM, et al. Closed-loop ventilation. Curr Opin Crit Care. 2023 Feb 1;29(1):19-25.

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