ECRONICON OPEN ACCESS

EC PULMONOLOGY AND RESPIRATORY MEDICINE

Review Article

# Adaptive Support Ventilation Version 1.1 State-of Art Literature Review

**Al-Otaibi***

*Registered Respiratory Therapist, Respiratory Care Department, King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia*

***Corresponding Author**: Osama Al-Otaibi, Registered Respiratory Therapist, Respiratory Care Department, King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia.

**Received:** June 27, 2018; **Published:** July 20, 2018

## Abstract

Adaptive support ventilation (ASV) is a complex computerized-based system. It uses the dual control to guarantee minute ventilation. Its operating system was updated to version 1.1, to protect the lungs from ventilator-induced lung injury by targeting an average of 7.5 ml/kg (IBW). The purpose of this paper is to provide an extensive state-of-Art literature review, and explore tidal volume readings in this improved design, while evaluating its safety application. In addition, ASV, and ASV option (intellivent) were discussed as well. In spite of the ASV intelligence. It is recommended to continue to monitor patients by doing ABGs, and by clinical examination, because limitation was shown in small number of patients due to poor $SPO_2$ signal. ASV deserve further studies. Especially, in obstructive patients, and paediatrics.

***Keywords:*** *Adaptive Support Ventilation; Computerized-Base System; Intellivent-ASV*

## Abbreviations

ASV: Adaptive Support Ventilation; IBW: Ideal Body Weight; KBS: Knowledge-Base System; VQ-attending: Goal-Directed Critiquing of Ventilator Management; ESTER: An Expert System for Management of Respiratory Weaning Therapy; CORE: Continuous Respiratory Evaluator; KUSIVAR: A Knowledge-Based Support System for Mechanical Ventilation of the Lungs; COPD: Chronic Obstructive Pulmonary Disease; ARDS: Adult Respiratory Distress Syndrome; CBW: Computer-Based Weaning; IDSS: Intelligent Decision Support System; TEE: Total Energy Expenditure; VT: Tidal Volume; IT: Inspiratory Time; TE: Expiratory Time; RCEXP: Expiratory Time Constant; ETS: Expiratory Trigger Sensitivity; P-RAMP: Pressure Ramp; TRC: Tube Resistance Compensation; $VO_2$: Oxygen Consumption; EE: Energy Expenditure; $SPO_2$: Saturation

## Introduction

Mechanical ventilation is a life-saving therapy that is used to support patients until their disease condition, is resolved or at least alleviated. It is used to sustain lives but cannot cure diseases. It has many complications, and hazards. And it must be discontinued as soon as possible, when patient condition allows [1].

There are many modalities of ventilation used in science. The respiratory Therapist, the intensivist or any clinician, who is managing ventilation must have a thorough understanding of the proper initiation, management, ventilator design, theory of operation, and clinical application, to safely match the ventilator capabilities with patient's physiological needs [2].

To understand the complexity of ASV, we have to know that a control variable is "the variable that is pre-determined for a given inspiration". Predetermined means the operator presets a parameter independently of patient lung mechanics. For example, in Volume control; the operator presets tidal volume, and flow, which will result in a stable minute volume, but variable pressure readings. But, in Pressure control, the user will set a preset pressure, but the volume will be variable according to lung mechanics. This might result in more patient synchrony, and comfort, as inspiratory flow is not consistent with a preset value. On the other hand, a more advanced form of ventilation that can switch between pressure control, and volume control is called Dual control, the main objective of dual control is to guarantee the minute volume, while maximizing patient- ventilator synchrony [3].

### Targeting schemes

There are two ways in which the mechanical ventilator control variables open-loop control, and close-loop control.

### Open-loop control

Means the control unit of ventilation makes no adjustment for changes in patient condition, lung mechanics or leaks. An example of that is the intrapulmonary percussive ventilation, in which the flow into the patient lungs is a function of the impedance of the respiratory system [4].

### Close-loop system

The closed-loop control will provide a positive or negative feedback of information about the patient ventilator condition based on values measured continuously. There are two common ways for closed-loop: It includes (inter-breaths), which is the control between breaths, and (intra-breaths) which is the control within the same breath. In the closed-loop system, gas output is measured by comparing input, and output data. If there is difference between the two values, the system will generate an error that will force the feedback control to match both values. This difference will happen if there is a leakage in the circuit, or disturbances in lung mechanics [5]. Figure 1 will show a graphical demonstration of Closed-loop feedback system.

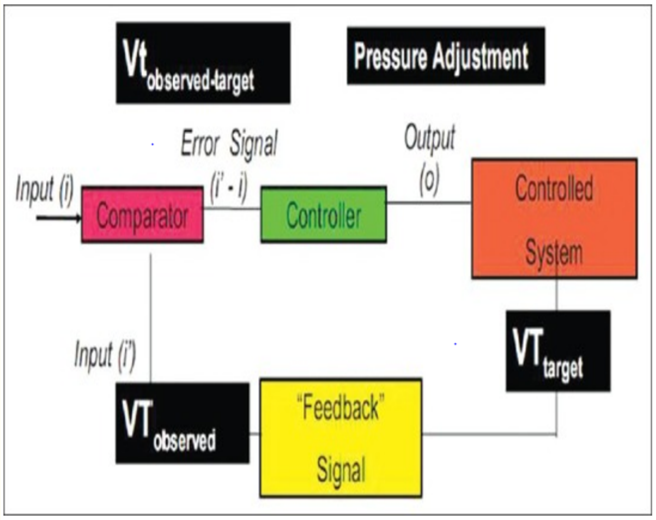


***Figure 1:*** *Closed-loop feedback system.*

There are also six targeting schemes in closed-loop control: (set-point, dual, servo, adaptive, optimal, and intelligent). These schemes are the cornerstone of many ventilator modes. Once the user become familiar with them, confusion will be less likely to happen.

### Set-point

Set-point targeting, is when the operator set the maximum pressure or flow, and the ventilator maintains that value as an output.

### Dual

Is a more advance version of set-points, in which Delivered pressure, volume, and flow can be measured and used as feedback information to control the driving mechanism. The mechanical ventilator have the option to choose whether the breath is volume or pressure, based on operator settings. Also, the breath may start in volume control, but automatically, switch to pressure control as in Drager Pmax mode, or the opposite in Bird VAPS. In servo-I Maquet, if user set the tidal volume and inspiratory time in volume control, and patient makes an effort that decrease inspiratory pressure by 3 cm H2O, the machine will switch to pressure control. In addition, if the tidal volume setting is small, and inspiratory time is short, combined with a large inspiratory effort, the delivered breath will not be distinguished from Pressure supported breaths [4]. Other examples of ventilators that provide dual modes are; Autoflow (Drager Evita 4 and XL), Pressure Regulated Volume Control and Volume Support (Maquette Servo-ι), Volume Control + (Puritan Bennett 840), Pressure Regulated Volume Control (Viasys/Pulmonectics PalmTop ventilator and Viasys Avea), and the Adaptive Support Ventilation (ASV) (Hamilton Galileo) [6].

### Servo

Track a moving input, The output is forced to follow a dynamic, varying, operator-specified input such as in proportional assisted mode, where the ventilator follows the patient's own effort, and support the abnormal loading on respiratory muscles caused by disease, without compromising normal workload done by the respiratory muscles. It is similar to power steering on automobiles.

### Adaptive

It automatically, and independently adjust a set-point to maintain an operator desired set-point. An example of an adaptive control is Pressure regulated volume control in Siemens servo 300. The difference between set-point targeting and adaptive targeting is that the former works within breaths only, while the latter can offer pressure targeting within breaths, and volume targeting between breaths.

### Optimal

Allow the user to set both pressure, and volume set-points. It is optimal, because it uses a mathematical model to find the best performance function by targeting a patients' ventilatory pattern to either minimize or maximize some overall performance characteristics. This kind of ventilator will make all subsequent adjustments automatically, after the user sets a desired minute ventilation. Hamilton medical is the only company, which makes this feature. The term "Adaptive" had caused some confusion among professionals.

### Intelligent

Refer to the use of artificial intelligence methods such as; fuzzy logic, rule-based expert systems, neural networks, and knowledge-based system (KBS) for targeting strategies. The (KBS) tries to make use of human experience, and expand it to control all parameters of ventilation. A simple example is the automatic adjustment of pressure support in Drager Smartcare mode [7].

### Computer-Base weaning

The need for computer-base technology could be a necessity, as medical errors still a serious problem worldwide. A recent study by Johns Hopkins claims [8] that more than 250,000 people in the U.S. die every year from medical errors. Other reports mention that the numbers to be as high as 440,000. Medical errors are the third-leading cause of death after heart disease and cancer. In addition, the financial costs associated with injuries range between 17 - 19.5 Billion dollars as of 2008. With adjusted increase in US population to be 20.8 billion dollars. Some authors mentioned that if quality-adjusted life criteria is added, the actual cost could be significantly higher [9].

In addition, the expectation still very high from healthcare providers. Especially, in the intensive care units, where large amount of information need to be processed quickly, and efficiently in a relatively short period of time. Also, the cost associated with running mechanical ventilations, especially, with long duration of ventilation, is high as well. These factors have led to the trend toward the use of computerized-decision support and knowledge-based expert systems. Ideally, in weaning mechanical ventilation, because, weaning is time consuming, and needs frequent monitoring, and adjustments. If a computer control can accelerate the process, while being monitored by a qualified clinician. It will save time, and money.

One study compared a physician-directed weaning to computer-based weaning. The computer-based weaning resulted in less frequent assessment of ABGs, and shorter weaning time. Another study showed that a computerized hand-held weaning protocol used by respiratory therapists was more effective that using a paper-based weaning protocol. ASV is an example of a computer-controlled mechanical ventilation. Several complex systems have been developed as well like; VQ attending, ESTER, continuous respiratory evaluator (CORE), KUSIVAR, WEAN-PRO, and Ventilation manager [10].

To understand the details of ASV. A brief overview of the design of decision support systems is provided. These systems use different methodologies to operate mechanical ventilation. They include rule-based design, model-base design or the combination of the two.

### Rule-based systems

Use pre-designed clinical protocols, and guidelines to establish patient ventilator parameters. Some use statistical models, which is different than physiological models.

### Model-based systems

Simulate physiological models to find the treatments options.

### Rule-based + model-based system

Combine both systems by using clinical guidelines with physiological model. ASV uses adaptive clinical guidelines, and rules, which are derived from physiological models.

Also, the design could be used for:

- The management of one phase of ventilation. e.g. Weaning.
- Regulation of blood gases.
- Acceleration of weaning.
- Providing advice to the clinician.

- Control ventilation.
- Certain patient category such as Adult, pediatric, or neonate.
- Certain disease like COPD, or ARDS.

## Intelligent decision support systems (IDSSs)

In mechanical ventilation can be designed as an expert advisory system or used for automatic control of ventilation. These systems can use certain patient data, process them, and show the treatment options. The input data, could be retrieved automatically by sensors or entered manually by the user. Figure 2 shows a diagram of an IDSS for mechanical ventilation.

As shown in figure 2 an input data from both clinician, and patient will transfer to an analyser validator by comparing them to pre-set acceptable values. Then validate data will go to data smoother to prevent sudden changes to patient's ventilator parameters. After that, the output will reach the processing unit to determine the appropriate treatment, which will be shown to the clinician in graphical display or adjusted automatically by the ventilator control unit. If patient measured data are out of range, a displayed alarm will appear for the clinician [11].

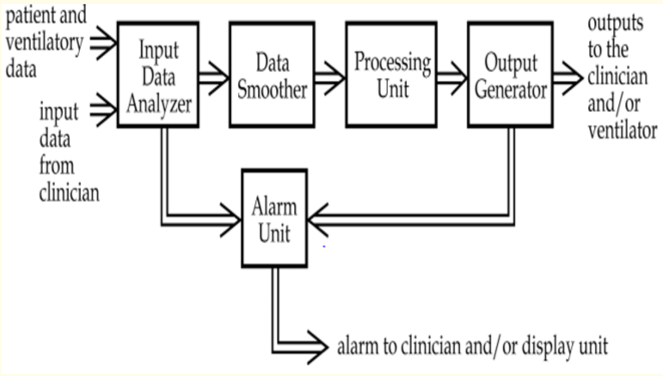


***Figure 2:*** *Intelligent decision support systems (IDSSs).*

## History of ASV

In 1977, Hewlett., *et al.* introduced mandatory minute volume (MMV). Which is a mode of ventilation in which the operator preset a target minute volume. If the patient breathing results in low minute volume, the machine will deliver either volume or pressure-controlled mandatory breaths, to maintain same minute volume. The use of MMV was associated with many complications such as rapid shallow breathing, development of inadvertent PEEP, dead space ventilation, and high tidal volumes (Hamilton manual).

The need to minimize those risks was necessary. Therefore, Adaptive support ventilation (ASV) originated and credited to Dr. Fleur T Tehrani (clinical engineering professor at the University of California, USA) who modified a version of the equation described by Otis., *et al.* in 1950 [5].

ASV is an advanced, closed-loop control mode of mechanical ventilation, which maintains a minimum minute volume preset by the operator regardless of patients' activity. The machine selects a VT and respiratory rate that the patient's brain would probably select if the patient was not connected to a ventilator. This pattern will augment spontaneous breathing. In addition, the optimum ventilator strategy will use the least total energy expenditure (TEE), while maintaining patients' requirements. Thus, It can be used for total or partial ventilatory support during the initiation, maintenance or weaning from mechanical ventilation.

### ASV Theory of operation (1998-2015)

ASV uses the Principle of Otis equation, with the minimum WOB, targeting a tidal volume of (8 - 10) kg, with an average of 9 ml/kg according to the time constant of the respiratory system.

$$f_w = \frac{\sqrt{1 + 4\pi^2 RC\dot{V}_A/V_D} - 1}{2\pi^2 RC}$$

Where:

Fw = minimum work frequency

RC= time constant of the mechanical system.

VA/VD= The alveolar-dead space ventilation ratio.

Figure 3 show that in point A the tidal volume is high, with low RR. This will result in significant effort to overcome elastic pulmonary, and thoracic forces. Where in point B there is very high muscular effort to overcome flow, combined with tachypnea. Therefore, the best option for the ventilator is to target point C. However, ASV can use point A as a target in patients with obstructive lung diseases, and target point B for patients with restrictive lung diseases [5].

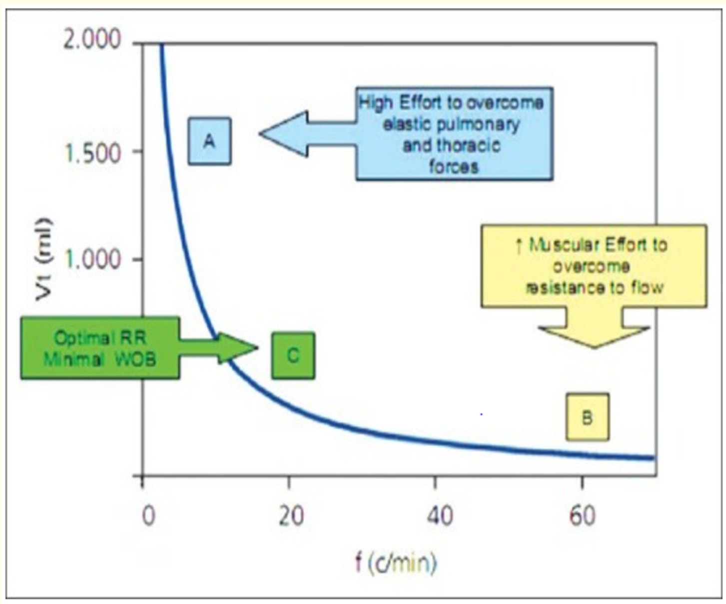


***Figure 3:*** *Tidal volume against RR.*

### ASV 1.1 Theory of operation (2016)

Due to the high risk of ventilator induced lung injury associated with high tidal volumes. Also, one study showed that tidal volumes are actually higher than what is established by Hamilton company [7]. The operation of ASV was revised by adding Meads Formula, while targeting an average of 7.5 ml/kg of tidal volume [12]. The optimal respiratory rate (RR) will Consider the average between Otis and Mead Formulas.

Otis Formula + Meads Formula

Minimum work of breathing minimum force of breathing [13].

$$f = \left(\frac{MinVol - f \cdot Vd}{Vd}\right)^{1/3} \cdot \left(2\pi \cdot RCe\right)^{-2/3}$$

Where:

f = is the respiratory rate.

VD = Deadspace.

RCe= airway resistance X respiratory compliance = expiratory time constant.

Alveolar ventilation = MV – (f X VD).

VA/VD= represent the alveolar-dead space ventilation ratio.

### ASV general concept

The operator will select 3 parameters only; the desired minute volume in MV%, PEEP, and $FIO_2$, then the machine will select the pattern, and calculate the minute ventilation according to the weight:

- >= 30 kg 100 ml/min per kg (IBW for adults).
- <30 kg 100–200 ml/min per kg.
- ABW 3–5 kg 300 ml/min per kg.

The minimum patient weight should be 5 kg.

### The calculation will be as follows:

- >30 kg VE = 100X (MinV%/100) X IBW (kg) [14]
- 15-30 kg VE = (100-200) X (MinV%/100) X IBW(kg)
- 5-15 kg VE= (200-300) X (MinV%/100) X IBW(kg) [15]
- 3-5 kg VE= 300 X (MinV%/100) X IBW(kg). See Figure below for explanation:

***Maximum RR in ASV:***

*is the smallest value of the following condition.*

*- 60 b/min.*

*- 23 b/min * %MinVol /100 / (Weight ≥ 30 kg) - 20/RCexp.*

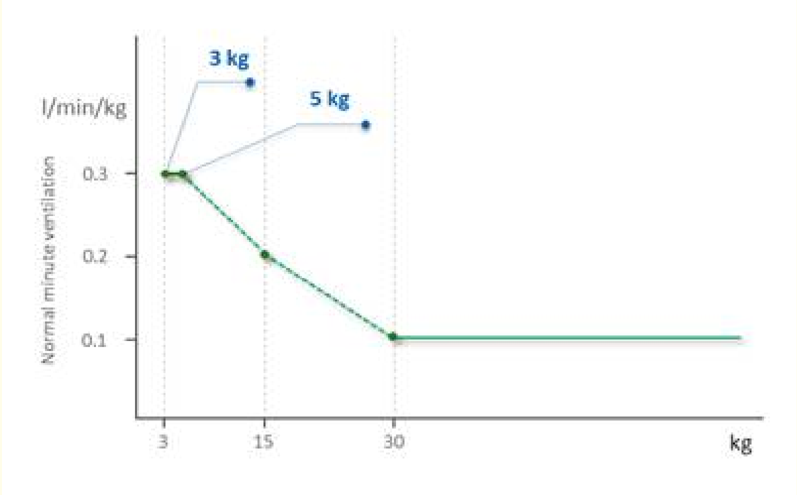


***Figure :** Shows a graphical demonstration of minute volume calculation according to the weight:*

### The company suggested parameters for use [17]

| MinV % | Setting |
|---|---|
| Normal patient | 100% to 110% |
| COPD | 90% |
| ARDS | 120% |
| If temp > 38.5 | Add 20% |
| Patient is 500 m ( 1640 ft) above sea level | Add 5% |
| Use HME | Add 10% |

***Table 1:*** *Suggested values by Hamilton Company.*

### ASV algorithm

For a given MinV%, the RR, and VT combinations are chosen based upon the minimum WOB, and Minimum Force of breathing. Pplat and total PEEP are measured by a 5 sec end-inspiratory and end-expiratory occlusion respectively. ΔP is calculated as the difference between Pplat and PEEP tot.

The ventilator will provide three test breaths, starting with low pressure, and calculate the VT, C, R, and RR, to determine the elastic, and resistive forces of the lung. The pressure used fall into the safety limits within the unit table 2. Then, patient is classified into one of the three predefined lung conditions (normal lung, ARDS, or COPD). A Statistical significance is assumed for P values below 0.05. Also, ASV select lung protective ventilation with limited driving pressure in passive ICU patients with different lung conditions [18].

### The preselected safety limits

| | |
|---|---|
| Minimum pressure | PEEP+5 |
| Maximum pressure | Pmax-10 |
| Vt minimum | 4.4 ml/kg ( 2 X Vd) |
| Vt Max | 15ml/kg |
| Minimum mandatory RR | 5 breaths/min |
| Max mandatory RR | 60/3 RC (time constant) |
| ** Minimum TI | RCexp or 0.5 s, whichever is larger |
| Max TI | 2s for Adults respectively ,1.5s for paediatrics |
| Minimum TE | 2 * RCexp or 0.5 s, whichever is larger |
| *** Set TE | TE is set to 3.5 * RCexp to minimise intrinsic PEEP |
| Vt limit | 1.5 X Vt high alarm limit |
| Max TE | 12 Seconds |
| Max Minute volume | 350% |

***Table 2:*** *ASV safety limits.*

*** If TImin is larger than TImax then TImin is set to TImax.*

**** If TE is smaller than TEmin, TE is set to Temin.*

****If TE is larger than TEmax, TE is set to TEmax.*

## Breathe delivery

After lung condition had been chosen, ASV will use a pressure -targeted breaths. It will adjust the mandatory rate, and inspiratory pressure to reach the desired minute volume. As shown in this figure 4.

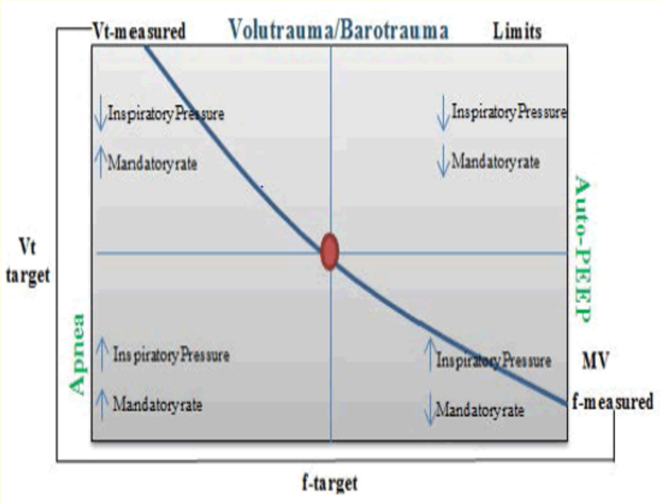


***Figure 4:*** *Lung protective strategies [19]:*

- *In the left upper quadrant; VT high, and RR are low, the Pins pressure will decrease, and RR will increase.*
- *In the lower left quadrant; VT, and RR are low, Pins, and RR will be increased.*
- *In the right upper quadrant VT, and RR are high. Pins, and RR will be decreased.*
- *In the right lower quadrant, VT is low, and RR is high. ASV will increase Pins, and decreased RR.*

## Common situations in Breath delivery during ASV

- If the patient is not breathing, SIMV (Pressure control) breaths are provided.
- If patient assists a breath, a pressure supported breath is delivered with the same amount of pressure assisted.
- If the patient is breathing some, but not enough to get the desired minute ventilation, then, the spontaneous breaths will be pressure supported, and a time-triggered breath will be pressure controlled [18].

## Other parameters

### RCexp

The expiratory time constant (RCexp) is obtained from the expiratory flow-volume curve and can be estimated on a breath-by-breath basis. Values are shown in table 3.

| RCexp | Value |
|---|---|
| Normal | 0.6 to 0.9 |
| ARDS | < 0.6 |
| COPD | > 0.9 |

***Table 3:*** *RCexp values.*

## RCexp value interpretation

**Imposed WOB during ASV:**

To prevent the imposed WOB, the operator must optimize the following parameters according to the patient lung pathology:

1. **P-Ramp:** Is the rise time during ventilation, operator must be careful if it is very slows, as this will decrease breath delivery, and compromise patients' demands. Default is 25 ms.

2. **Expiratory trigger sensitivity (ETS):** Must be adjusted if patient exhale early, actively breathing or the waveform shows a short inspiratory time. See table 4.

| | |
|---|---|
| ETS default | 25% |
| Normal value | 30% to 35% |
| COPD | 40% to 70% |

***Table 4:*** *ETS values.*

3. **Tube resistance compensation (TRC):** After the user have chosen ETT or trach, the level of compensation must be set to 100%.

4. **Flow trigger:** Set from 2 to 5 L/min [20].

## IntelliVent-ASV

Is a mode option available in ASV. It is a full automation of mechanical ventilation. Three tools must be available to use it. First, the user must connect an End-tidal $CO_2$ to the patient Y to monitor $PETCO_2$. Second, use $SPO_2$ for monitoring Saturation. Finally, a proximal flow sensor should be used to measure the expiratory time constant, for the purpose of monitoring lung mechanics. Then user select the patient condition from the following:

1. Normal lungs.
2. Chronic hypercapnia.
3. ARDS.
4. Brain injury.

The ventilator will change the default settings according to the condition used. There will be other options like for example:

1. Quick wean option.
2. Automatic recruitment maneuver with minimum/maximum PEEP desired.
3. Heart-Lung index to limit use of PEEP for specific patients.

In Passive patients, (no spontaneous effort), the regulation of ventilation will be by adjusting minute volume, and in active patients, the regulation of ventilation will be according to the respiratory rate of the patient.

## Discussion

In 2008, a Prospective observational cohort study of 243 patients, who underwent 1327 days of ASV ventilation examined the respiratory rate-tidal volume combination in different lung pathologies, the tidal volume, in passive normal lungs was (8.3 ml/kg/PBW), in COPD (9.3 ml/kg/PBW), With RR (14/min), but in passive ALI/ARDS was 7.6ml/kg (6.7 - 8.8), With RR of (18/min). In addition, the VT-RR combinations in patients who triggers the ventilator did not show any difference between COPD, ALI/ARDS, and normal lungs [22].

In 2010, Another Prospective crossover interventional multicenter trial in Six European academic intensive care units, compared the short-term effects of (ASV), to volume control or pressure control in Eighty-eight passive patients with respiratory failure. They were subjected into three groups: patients with normal lung (n = 22), restrictive lung disease (n = 36) or obstructive lung disease (n = 30). Results Showed a low respiratory rate (7/min), and high tidal volume in 3 COPD patients with severe airway obstruction ranging from 18.6 ml/kg to (22.1 ml/kg) [23].

On the other hand, A prospective randomized crossover comparative study was conducted in a 12-bed ICU in a general hospital. Two hours of ventilation were randomly applied as ASV or Intellivent-ASV in 50 sedated patients. Tidal volume, respiratory rate, inspiratory pressure, $SPO_2$, and $ETCO_2$ were measured, and recorded continuously. Then, mean values were calculated. Also, $FIO_2$, and plateau pressure reading are recorded as well. Results revealed a lower values of minute volume, $FIO_2$, and plateau pressure in intellivent-ASV compared to ASV. Also, V T decreased from 8.3 (7.8 - 9.0) to 8.1 (7.7 - 8.6) mL/kg PBW with (p = 0.003). There were no safety concerns in this study [20].

An interesting prospective observational comparative study included 100 consecutive patients who were invasively ventilated by IntelliVent-ASV for a total of 392 days. The Inclusion criteria were, ventilation of less than 24 hours at the time of inclusion, and an expected duration of ventilation of more than 12 hours. The exclusion criteria were; Readiness to wean, presence of Bronchopleural fistula, and Brain death. In passive patients, the tidal volume (VT), for predicted body weight (PBW) was in normal lung (n = 45) 8.1 (7.3 to 8.9) mL/kg, ARDS (n = 16) 7.5 (6.9 to 7.9) mL/kg and COPD patients (n = 19); 9.9 (8.3 to 11.1) mL/kg, respectively; P 0.05). Patient assessment was done once a day, not continuously during this observational study. Tidal volume delivery was high in COPD patients 9.9 ml/kg compared to other diseases [21].

In 2016, a randomized control trial compared the efficacy of ventilation in ASV-intellivent (version 1.1), its safety, and the workload of the health care team, to Pressure assist control, and pressure support mode over 48h window in eighty-eight patients. During the trial: ASV-intellivent was safe, required less manual adjustment by operator, and used variable ventilating pressures, and PEEP [24].

Furthermore, a prospective observational study done in 2016, with 120 patients measured the ΔP, tidal volume and plateau pressure table 5, in ASV 1.1 during different lung conditions, normal (N = 49), ARDS mild (N = 17), ARDS moderate (N = 32), ARDS severe (N = 13), and COPD (N = 9) [26].

| Normal lungs | ARDS mild | ARDS moderate | ARDS severe | COPD | P(Anova) |
|---|---|---|---|---|---|
| ΔP | 9 (8-10) $cmH_2O$ | 10 (9-11) $cmH_2O$ | 10 (8-13) $cmH_2O$ | 11 (6-12) $cmH_2O$ | 0.127 |
| VT in ml/IBW | 7.5 (6.6-8.1) | 6.8 (6.3-7.5) | 6.6 (6.1-7.0) | 9.3 (6.9-11.1) | 0.001 |
| Plateau | 16 (14-18) $cmH_2O$ | 21 (17-24) $cmH_2O$ | 22 (20-24) $cmH_2O$ | 20 (18-22) $cmH_2O$ | < 0.001 |

*Measured values during study*

ASV 1.1 update compared to previous version may show a reduction in tidal volume in healthy subjects, but similar results in patient in COPD or ARDS. There were significantly high values of VT up to 22 ml/kg in older version of ASV [23], but sample size was very small (n = 3). There are no safety issues in ventilating COPD patients, because no agreement on the optimal VT for COPD patients is available in literature. These patients have high end-expiratory lung volume, in which lung strain with high volume still limited. Further studies are needed to assess the optimal tidal volume for COPD patients. In addition, to the use of ASV in paediatrics > 5 kg. ASV, And ASV 1.1 both resulted in safe ventilation, with higher VT in obstructive diseases. ASV-intellivent revealed a much lower values of VT compared to ASV in some studies [21].

In 2018, A recent randomized crossover study in seventeen patients designed to assess the metabolic load, like oxygen consumption ($VO_2$), or Energy expenditure (EE) during various Pressure support levels in comparison to ASV by using the same minute volume. Results; showed a lower metabolic load during ASV compared to Pressure support. These lower values could be attributed to the improved design of ASV 1.1, because of the addition of Meads Formula, minimum force of breathing, combined to Otis Formula, minimum work of breathing [25].

## Conclusion

There is no doubt that a well-skilled clinician who ventilate patients by using a computerized-based system will be able to make complex decisions in time, compared to those who don't have access to such technology. In spite of the ASV intelligence. It is recommended to continue to monitor patients by doing ABGs, and by clinical examination, because limitation was shown in very small number of patients due to poor $SPO_2$ signal. ASV is a safe modality of ventilation. it minimizes the operator manual adjustments. It uses variable pressures during ventilation. To conclude, ASV mode could be a promising modality of ventilation, and deserve further studies.

### Conflicts of Interest

There are no conflicts of interest.

## Bibliography

1. Egan's fundamentals of respiratory care p.1200.
2. Egan's fundamentals of respiratory care p.1006.
3. Egan's fundamentals of respiratory care p.1019.
4. Egan's fundamentals of respiratory care page. 1022.
5. Jaime Fernández., *et al*. "Adaptive support ventilation: State of the art review". *Indian Journal of Critical Care Medicine* 17.1 (2013): 16-22.
6. SC Chen., *et al*. "Adaptive Support Ventilation: Review of the Literature and Clinical Applications". *Journal of Internal Medicine of Taiwan* 19.6 (2008): 465-471.
7. Egan's fundamentals of respiratory care p.1023.
8. "Study Suggests Medical Errors Now Third Leading Cause of Death in the U.S". Johns Hopkins medicine.
9. Ken Perez. "The Human and Economic Costs of Medical Errors". hfma.
10. Egan's fundamentals of respiratory care p.1217.
11. Fleur T Tehrani. "Computerized Decision Support Systems for Mechanical Ventilation". In book: Efficient Decision Support Systems - Practice and Challenges in Biomedical Related Domain (2011).
12. Hamilition company references.
13. Control of respiratory frequency Jere Mead (1960).
14. Mosby respiratory care equipment book (488).
15. Hamilition clinical application specialist.
16. Mosby respiratory care equipment book (490).
17. Hamilton company manual.
18. Mosby respiratory care equipment book (491-492).
19. Umesh K Bylappa., *et al*. "Closed Loop Control: A Newer Mode of Mechanical Ventilation". Journal of Clinical Medicine and Therapeutics 2 (2017): 18.
20. Jean-Michel Arnal., *et al*. "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". *Intensive Care Medicine* 38.5 (2012): 781-787.

21. Jean-Michel Arnal., *et al*. "Feasibility study on full closed-loop control ventilation (IntelliVent-ASV™) in ICU patients with acute respiratory failure: a prospective observational comparative study". *Critical Care* 17 (2013): R196.

22. Arnal JM., *et al*. "Automatic selection of breathing pattern using adaptive support ventilation". *Intensive Care Medicine* 34.1 (2008): 75-81.

23. Giorgio A Iotti., *et al*. "Adaptive support ventilation versus conventional ventilation for total ventilatory support in acute respiratory failure". *Intensive Care Medicine* 36.8 (2010): 1371-1379.

24. Bialais E., *et al*. "Closed-loop ventilation mode (IntelliVent®-ASV) in intensive care unit: a randomized trial". *Minerva Anestesiologica* (2016).

25. HW Hsu., *et al*. "Comparison of the Metabolic Load in Patient Ventilated with Pressure Support Ventilation and Adaptive Support Ventilation Mode with the Same Minute Ventilation". *American Journal of Respiratory and Critical Care Medicine* 197 (2018): A2550

26. Arnal JM., *et al*. "ASV - Adaptive Support Ventilation". *Intensive Care Medicine* (2016) [abstract]

**Volume 7 Issue 8 August 2018**