# Adaptive support ventilation versus synchronized intermittent mandatory ventilation in patients with chronic obstructive pulmonary disease

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Adaptive support ventilation (ASV) is a fully automated closed-loop ventilation mode that can act as pressure support (PS) and pressure-controlled ventilation. The aim of this study was to evaluate the benefits of using ASV in the initiation, maintenance, and weaning phases of the mechanical ventilation in comparison with synchronized intermittent mandatory ventilation (SIMV)+PS mode in patients with chronic obstructive pulmonary disease (COPD). Sixty patients with COPD requiring mechanical ventilation were recruited in this study. Among them, 37 patients were treated by SIMV+PS, whereas 23 patients were assigned for ASV. After resolution of the cause of acute respiratory failure, assessment of readiness for weaning was done. Patients were followed after 30, 60 min, and 24 h. Ventilator and hospital outcomes were recorded. Compared with SIMV+PS, ASV provided shorter weaning time (27.3 ± 12.3 vs. 62 ± 14.1 h). Moreover, there was a shorter hospital stay of 14.83 ± 6.14 for ASV group compared with 22.14 ± 17.39 days for SIMV+PS, with similar weaning failure rates, death rate, and intubation period in both groups. This study proved that ASV mode was successful as a mode of initiation, maintenance, and weaning in acute exacerbation of patients with COPD requiring mechanical ventilation with a shorter weaning time and shorter hospital stay compared with SIMV+PS mode.

**Keywords:**
adaptive support ventilation, chronic obstructive pulmonary disease, expiratory time constant, synchronized intermittent mandatory ventilation

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## Introduction

Chronic obstructive pulmonary disease (COPD) is a disease with an increasing prevalence and mortality that is characterized by persistent respiratory symptoms and airflow limitation owing to airway and/or alveolar abnormalities because of exposure to noxious particles and gases [1–3].

Mechanical ventilation is a procedure used in ICUs. Despite being a technology that can save life, it is not devoid of risk, and if not used properly, it may even exacerbate lung damage or worsen the clinical outcomes.

The main objective of most ventilation support systems is to maintain both adequate oxygenation and ventilation; it reduces the work of breathing and improves the comfort of the patient until the condition that forced the need for this technique has been alleviated [2].

In an effort to meet these objectives, a variety of ventilatory modes have been developed that can potentially reduce complications, shorten the duration of mechanical ventilation, and thus improve clinical outcomes. Patients with acute exacerbations of COPD require either noninvasive mechanical ventilation or invasive mechanical ventilation [1–3].

Adaptive support ventilation (ASV) is a fully automated closed-loop ventilation mode, considered as pressure control minute volume guaranteed mode that depends on Otis equation that describe change in respiratory rate (RR) and tidal volume to use the least energy and least work of breathing [4,5].

ASV provides automatic ventilation by calculation of expiratory time constant (RCexp) [inspiratory resistant (Rinsp)×static compliance (Comp stat)] from which the appropriate RR is selected to achieve the most appropriate ventilatory pattern.

In passive patient, the ventilator automatically adjusts the inspiratory pressure and the RR to achieve the target minute volume but in patients who are able to

trigger a breath, the ventilator adjusts the inspiratory pressure and RR to achieve the target minute volume, and if the RR is below the target, the ventilator delivers pressure-controlled breath [6].

## Patients and methods

This study was conducted at Assiut University Hospital Respiratory ICU. Data were collected over a period of 10 months (from September 2015 to June 2016). A written informed consent was obtained from the patient's relatives. We recruited 60 patients with COPD in Respiratory ICU owing to acute exacerbation. Patients who had concomitant musculoskeletal disease or those with combined etiologies, for example, idiopathic pulmonary fibrosis or pneumonia, were excluded from the study. Institutional Review board in Assiut Faculty of Medicine approved the study.

Intubation was done through the orotracheal route with an endotracheal tube having internal diameter of 7.5–8 mm. We classified the patients into two groups: for group 1, we used synchronized intermittent mandatory ventilation with pressure support (SIMV+PS), and for group 2, we used ASV. For SIMV+PS group, we used Bennett or Engstrom ventilators (Engstrom care station, GE Healthcare Datex ohmeda, Madison, USA), whereas for ASV group, we used a microprocessor-controlled mechanical ventilator (Galileo GOLD; Hamilton Medical AG, Bonaduz, Switzerland).

For SIMV+PS group, ventilator settings were RR of 10–14/min, tidal volume of 6–8 ml/kg from ideal body weight (IBW), fraction of inspired oxygen to obtain a saturation of 88–92% with a positive end-expiratory pressure (PEEP) of 5 $cmH_2O$, expiratory trigger sensitivity of 40%, flow rate of 60–80 l/min, and peak inspiratory pressure of less than 40–45 $cmH_2O$; moreover, P plateau of less than 30 $cmH_2O$ is acceptable and an I: E ratio of 1: 3–1: 5 was initiated.

In contrast, ventilator setting for ASV group was done by selecting the patient's sex and height from which the IBW was automatically calculated. Then minute volume of 100% was selected that corresponds to 100 ml/kg from IBW. ASV pressure limit was chosen at 30 $cmH_2O$, fraction of inspired oxygen was adjusted to obtain a saturation of 88–92%, and PEEP of 5 $cmH_2O$ was selected. For pressure triggered patients, 1–3 $cmH_2O$ was selected, whereas for flow triggered patients, 1–3 l/min was selected.

On admission to ICU, full medical history from the patient's relatives, full clinical examination, plain chest radiography, ECG, arterial blood gases analysis, serum electrolytes (Na+, K+, Mg+, Ca++), hematocrit, serum albumin, liver function tests, and kidney function tests were carried out.

After resolution of the cause of acute respiratory failure, assessment of readiness for weaning was done. For SIMV+PS group, the initial level of PS (above PEEP) was set at 15 $cmH_2O$ then was evaluated every 30 min and titrated to keep the RR less than 35 breaths/min and gradually decreased to 7 $cmH_2O$ by 2 $cmH_2O$ increments [5].

In ASV group, the minute volume was decreased to 70% then to 50% then to 30% every 30 min to achieve lower PS levels to prepare the patient for extubation.

## Results

Table 1 shows gasometric parameters before weaning with significant oxygen saturation in favor ASV group.

Table 2 shows gasometric parameters after 1 h of intubation with insignificant difference between both groups.

Table 3 shows gasometric parameters before weaning with significant oxygen saturation in favor ASV group.

Table 4 shows assessment of gasometric parameters in both groups 1 day after weaning with statistically significant difference as regards pH value, but both values were within acceptable ranges. The difference

**Table 1 Patients' demographics in both groups of patients with mechanically ventilated chronic obstructive pulmonary disease in the study**

| | SIMV (*n*=37) [*n* (%)] | ASV (*n*=23) [*n* (%)] | *P* |
|---|---|---|---|
| Sex | | | |
| Male | 30 (81.1) | 16 (69.6) | 0.305 |
| Female | 7 (18.9) | 7 (30.4) | 0.34 |
| Age (years) | | | |
| Mean±SD | 61.81±9.47 | 64.13±6.75 | 0.310 |
| Range | 42.0-81.0 | 49.0-80.0 | |
| Smoking | | | |
| Smoker | 30 (81.1) | 16 (69.6) | 0.305 |
| Nonsmoker | 7 (18.9) | 7 (30.4) | |
| Smoking index | | | |
| Mean±SD | 697.33±317.96 | 721.25±423.98 | 0.830 |
| Range | 200-1600 | 140-1600 | |
| Number of exacerbation/year | | | |
| 1 | 12 (32.4) | 9 (39.1) | 0.440 |
| 2 | 13 (35.1) | 10 (43.5) | |
| 3 or more | 12 (32.4) | 4 (17.4) | |

ASV, adaptive support ventilation; SIMV, synchronized intermittent mandatory ventilation.

as regards partial pressure of carbon dioxide, partial pressure of oxygen, bicarbonate level, and oxygen saturation values were insignificant.

Table 5 shows hemodynamics 1 h after extubation without statistically significant difference between both groups.

Table 6 shows statistically significant difference in favor of ASV being shorter hospital stay and weaning hours than SIMV+PS, while intubation period was insignificant.

Table 7 shows the outcome of weaning in both groups.

**Table 2 Gas metric parameters after 1 h of intubation in both groups**

| ABG | SIMV (*n*=37) | ASV (*n*=23) | *P* |
|---|---|---|---|
| pH | | | |
| Mean±SD | 7.36±0.07 | 7.38±0.06 | 0.578 |
| Range | 7.23-7.49 | 7.29-7.49 | |
| $PaCO_2$ | | | |
| Mean±SD | 60.70±14.73 | 65.43±11.43 | 0.120 |
| Range | 31-103 | 51-89 | |
| $PaO_2$ | | | |
| Mean±SD | 80.92±13.46 | 74.39±12.35 | 0.071 |
| Range | 56-101 | 56-100 | |
| $HCO_3$ | | | |
| Mean±SD | 34.05±8.02 | 40.65±8.58 | 0.06 |
| Range | 20-48 | 28-55 | |
| $SaO_2$ | | | |
| Mean±SD | 95.19±3.04 | 94.70±2.70 | 0.463 |
| Range | 90-100 | 89-100 | |

ABG, arterial blood gases; ASV, adaptive support ventilation; $HCO_3$, bicarbonate level; $PaCO_2$, partial pressure of carbon dioxide; $PaO_2$, partial pressure of oxygen; $SaO_2$, oxygen saturation; SIMV, synchronized intermittent mandatory ventilation.

**Table 3 Gasometric parameters before weaning in both study groups**

| ABG | SIMV (*n*=37) | ASV (*n*=23) | *P* |
|---|---|---|---|
| pH | | | |
| Mean±SD | 7.43±0.05 | 7.42±0.04 | 0.262 |
| Range | 7.36-7.52 | 7.36-7.5 | |
| $PaCO_2$ | | | |
| Mean±SD | 57.62±10.18 | 57.65±9.37 | 0.873 |
| Range | 42-80 | 39-74 | |
| $PaO_2$ | | | |
| Mean±SD | 77.00±18.73 | 78.48±20.74 | 0.781 |
| Range | 57-147 | 59-146 | |
| $HCO_3$ | | | |
| Mean±SD | 36.54±6.28 | 37.17±7.00 | 0.843 |
| Range | 26-53 | 28-54 | |
| $SaO_2$ | | | |
| Mean±SD | 94.49±2.58 | 96.26±2.32 | 0.012* |
| Range | 90-100 | 89-99 | |

**P*<0.05,statistically significant difference. ABG, arterial blood gases; ASV, adaptive support ventilation; $HCO_3$, bicarbonate level; $PaCO_2$, partial pressure of carbon dioxide; $PaO_2$, partial pressure of oxygen; SIMV, synchronized intermittent mandatory ventilation; $SO_2$, oxygen saturation.

Table 8 shows follow-up of weaning failure cases. For SIMV+PS group, the total weaning failure cases were 13/37. The majority of them (9/13; 69%) had been reintubated, the other three cases needed noninvasive ventilation during the first 48 h after extubation, whereas only one case had been tracheotomized. For ASV group, there were only three cases of weaning failure and all needed reintubation, with no statistically significant difference between the two groups.

## Discussion

This study proved that ASV mode was successful as a mode of initiation, maintenance, and weaning in acute exacerbation of patients with COPD with a shorter weaning time and shorter hospital stay when compared with SIMV+PS mode.

We found that the use of ASV mode was associated with significant improvement in oxygen saturation

**Table 4 Gasometric parameters in both groups 1 day after weaning**

| ABG | SIMV (*n*=37) | ASV (*n*=23) | *P* |
|---|---|---|---|
| pH | | | |
| Mean±SD | 7.41±0.06 | 7.38±0.04 | 0.044* |
| Range | 7.26-7.52 | 7.3-7.49 | |
| $PaCO_2$ | | | |
| Mean±SD | 62.38±10.51 | 61.52±8.98 | 0.751 |
| Range | 40-81 | 42-81 | |
| $PaO_2$ | | | |
| Mean±SD | 70.68±10.45 | 73.74±5.67 | 0.213 |
| Range | 55-98 | 55-79 | |
| $HCO_3$ | | | |
| Mean±SD | 37.22±6.20 | 38.22±5.33 | 0.507 |
| Range | 26-51 | 30-49 | |
| $SaO_2$ | | | |
| Mean±SD | 93.62±3.07 | 95.13±2.47 | 0.058 |
| Range | 88-100 | 88-96 | |

**P*<0.05, statistically significant difference. ABG, arterial blood gases; ASV, adaptive support ventilation; $HCO_3$, bicarbonate level; $PaCO_2$, partial pressure of carbon dioxide; $PaO_2$, partial pressure of oxygen; SIMV, synchronized intermittent mandatory ventilation; $SO_2$, oxygen saturation.

**Table 5 Hemodynamic parameters in both chronic obstructive pulmonary disease groups 1 h after extubation**

| Vital signs | SIMV (*n*=37) | ASV (*n*=23) | *P* |
|---|---|---|---|
| Systolic BP | | | |
| Mean±SD | 122.70±12.62 | 120.87±11.25 | 0.649 |
| Range | 100-150 | 100-140 | |
| Diastolic BP | | | |
| Mean±SD | 77.57±9.55 | 76.96±6.35 | 0.771 |
| Range | 60-90 | 70-90 | |
| Pulse | | | |
| Mean±SD | 95.11±15.91 | 95.61±20.32 | 0.957 |
| Range | 66-129 | 70-133 | |

ASV, adaptive support ventilation; BP, blood pressure; SIMV, synchronized intermittent mandatory ventilation. **P*<0.05, statistically significant difference.

**Table 6 Patients ICU outcome in both study groups**

| | SIMV (*n*=37) | ASV (*n*=23) | *P* |
|---|---|---|---|
| Hospital stay (days) | | | |
| Mean±SD | 22.14±17.39 | 14.83±6.14 | 0.050* |
| Weaning hours | | | |
| Mean±SD | 62±14.1 | 27.3±12.3 | 0.02* |
| Intubation period (days) | | | |
| Mean±SD | 8.16±3.72 | 7.17±3.10 | 0.347 |

*$P$<0.05,statistically significant difference. ASV, adaptive support ventilation; SIMV, synchronized intermittent mandatory ventilation.

**Table 7 Weaning outcome in both groups**

| Outcome | SIMV (*n*=37) [*n* (%)] | ASV (*n*=23) [*n* (%)] | *P* |
|---|---|---|---|
| Weaning failure | 13/37 (35.1) | 3/23 (13.0) | 0.060 |

ASV, adaptive support ventilation; SIMV, synchronized intermittent mandatory ventilation.

**Table 8 Follow-up of weaning failure cases**

| Follow-up of weaning failure cases | SIMV (*n*=13) [*n* (%)] | ASV (*n*=3) [*n* (%)] | *P* |
|---|---|---|---|
| Reintubation | 9/13 (69.2) | 3/3 (100.0) | 0.465 |
| Tracheostomy | 1/13 (7.6) | 0/3 (0.0) | 0.427 |
| Need of noninvasive ventilation | 3/13 (23) | 0/3 (0.0) | 0.142 |

ASV, adaptive support ventilation; SIMV, synchronized intermittent mandatory ventilation.

before and 1 h after weaning when compared with oxygen saturation in SIMV+PS, with no statistically significant difference in pH, partial pressure of carbon dioxide, and bicarbonate level. This was in agreement with Kirakli *et al.* [7], who found no statistically significant change in pH, partial pressure of carbon dioxide, and bicarbonate level during weaning. This improvement in oxygen saturation can be explained by appropriate selection of breathing pattern and RR by ASV mode and so the ideal I : E ratio that fits the patient's lung mechanics was achieved to minimize auto-PEEP.

Moreover, we found that ASV group had shorter duration of mechanical ventilation when compared with SIMV group, but the difference was statistically insignificant. This was in agreement with Sulzer *et al.* [8], who reported shorter duration of intubation and mechanical ventilation with ASV when compared with SIMV in postoperative coronary bypass patients, but the difference was statistically insignificant.

Moreover, Dongelmans and Schultz [9] agreed with the same results and reported that the percentage of patient's time on assisted mechanical ventilation (expressed as the median percentage of total duration of ventilation) was 43% in the ASV group and 52% in the control group. This shorter duration of the total mechanical ventilation period can be explained by the shorter weaning period in the ASV as it shows automatic switching to the PS mode when it detects spontaneous breaths by the patient [9].

Regarding weaning hours, we found that ASV provided shorter weaning time when compared with SIMV+PS. This was concomitant with the study by Kirakli *et al.* [7] in patients with COPD. They reported that ASV provided shorter weaning times (median: 24 vs. 72 h) when compared with pressure support ventilation (PSV).

In contrast, the study of Peter *et al.* [10] in postcardiac surgery patients reported that there were no differences between groups in period of tracheal intubation and ICU stay, and ventilator variables. These results suggest that in this specific population of patients, automation of postoperative ventilation with ASV resulted in an outcome similar to the control group. In their study, weaning times with ASV and PSV were comparable (16.4 and 16.3 h, respectively); however, the study was performed in cardiothoracic surgery patients with normal lungs. The shorter weaning times with ASV may be owing to the automation of inspiratory pressure levels (manually in PSV vs. automatic in ASV). The automation of inspiratory pressures with a computer-driven system may lead the patients to spend much more time in the comfort zone of ventilation [11].

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**Conflicts of interest**
There are no conflicts of interest.

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