Review

Adaptive Support Ventilation (ASV). Beneficial or not?

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Abstract

Ventilators functions and features have evolved with the advancement of technology along with the addition of microprocessors. It is important to understand and examine the benefits and risks associated with these advanced automated modes.

Adaptive Support Ventilation (ASV) is a mode that is unique to the Hamilton Medical ventilators, thereby limiting the number of clinicians who have experience with using this mode. ASV can make changes to respiratory rate and tidal volume and adjusting the driving pressure in the absence of a professional. ASV changes ventilator strategies when it detects changes to a patient's lung dynamics. The scope of ASV mode is not universally understood. Respiratory therapists may feel their position would be threatened with the use of smart automated modes.

This paper will aim to review the literature on the ASV mode of ventilation. The literature review will address the following research questions to broaden the understanding of the risks and benefits of the ASV mode. 1) Is the ASV mode effective for weaning patients? 2) Is ASV a safe mode of ventilation for patients with COPD and ARDS? 3) Is ASV a safe mode of ventilation with changes in lung dynamics? 4) Does ASV impact the bedside respiratory therapist?

Conclusions: ASV appears to be at least effective or even more superior to other modes especially during weaning off mechanical ventilation, and in other forms of respiratory failure. More studies in different clinical conditions and head-to-head with other modes.

Keywords: ASV, COPD, ARDS, Weaning

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Introduction

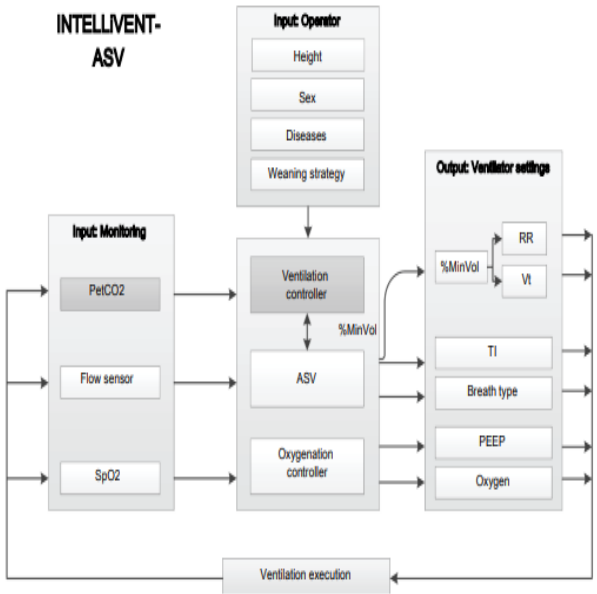
Hamilton Medical launched its original ASV mode in 1998. ASV is a closed loop system that automatically selects V_T and respiratory rate for mandatory breaths, and V_T for spontaneous breaths based on respiratory system mechanics and targeted minute ventilation.[1] Hamilton Medical ventilators utilizes a proximal flow sensor that provides precise measurements of flow and pressure at the patient's airway. The placement of the flow sensor at the patient's airway provides superior measurements compared to the measurements that are taken near the exhalation housing of other ventilators. The flow sensor does not add any additional dead space or weight to the circuit. Mucous and condensation may move through the sensor without affecting the function. The proximal flow sensor provides valuable measurements, which then allows the ventilator to make appropriate adjustments to the VT and respiratory rate based on breath-to-breath measurements.

In ASV mode, the ventilator calculates the resistance, compliance and auto-PEEP, and utilizes volume and pressure limited strategies. [2] The ASV mode adapts settings to the patient's physiology and respiratory mechanics (e.g., compliance, resistance, time constants) monitored with the flow sensor. The therapist sets the ideal body weight (based on patient's gender and height in cm), percent minute ventilation, positive end expiratory pressure (PEEP), fraction of inspired oxygen (FiO_2), and the maximum pressure alarm. The ratio of ventilation (based on IBW) and the percent minute ventilation is calculated to get the targeted minute ventilation (V_e). The targeted V_T is calculated as the minute ventilation divided by the frequency, and the pressure limit is adjusted to achieve an average delivered V_T equal to the target. The ventilator in ASV delivers mandatory breaths in an adaptive schema, in which the patient's work of breathing is minimized. The Otis and Mead equation, developed in 1950, [3] are utilized by ASV to ensure the least work of breathing. This equation states that there is a specific respiratory rate for each level of alveolar ventilation, that will achieve the lowest work of breathing. By calculating the targeted respiratory rate based on Otis equation, ASV can minimize the cumulative effects of compliance and resistance imposed on the respiratory system in a more energy efficient method. [3]

ASV also uses monitoring and lung protective strategies to safely adjust the way that each breath is delivered. Based on the patient's physiology and respiratory mechanics, the ventilator will adjust the
inspiratory to expiratory ratio (I:E) to avoid air trapping. Appropriate management of peak inspiratory pressures has also been an important factor in lung protective strategies. To address this management strategy, Hamilton Medical has programmed the ventilator to set the peak airway pressure al lowed to deliver the targeted (V_T) to ten cm H_2O below the high-pressure alarm. In addition to strategies that are intended to reduce or prevent auto-PEEP, barotrauma, and volu-trauma, the ASV mode can be used to ventilate patients throughout the course of mechanical ventilation. ASV is in fact not a single mode, but many modes in one. It acts as controlled mandatory ventilation (CMV) mode when there is no patient triggered breaths. When there are patient triggered breaths less than the targeted respiratory rate, ASV works similarly to synchronized intermittent mandatory ventilation (SIMV). ASV may also be a pressure support ventilation (PSV) mode when all breaths are patient triggered.[3]

In 2010, Hamilton Medical introduced the newer Intellivent-ASV mode which incorporates the original ASV mode. In addition to ASV providing optimal ventilation and protective strategies based on the patient's respiratory mechanics, the Intellivent-ASV mode also allows the clinician to select additional target values. Intellivent-ASV allows the clinician to dial in a $PetCO_2$ and SpO_2 target for the patient, which allows the ventilator to make automated changes to reach the targeted values. The PetCO2 target is reached by the ventilator's automated control of the percent minute volume. The patient's oxygenation target is reached by automated changes of PEEP and FiO_2.

In addition to the automation of targeting $PetCO_2$ and SpO_2 values, Intellivent-ASV also features a quick wean setting, which will decrease the ventilatory support to the patient and perform a spontaneous breathing trial (SBT) when weaning criteria is met. Figure 1 (reproduced with permission from Hamilton medical).



Weaning with ASV

Postoperative Cardiac Surgery Patients

Several studies [4,5,6,7,8,9,10,11] looked at postoperative coronary heart patients and the length of time the patient remained mechanically ventilated from the time of arrival to the intensive care unit (ICU) until extubation. Summary of those studies are listed in Table 1.

Zhu and colleagues [4] compared ASV versus physician directed weaning and collected data on sixty-eight post-operative cardiac valvular patients over a three-month period. The results showed that with ASV there was an average of two hours reduction in time on the ventilator for these patients.

Aghadavoudi and colleagues [5] published a randomized control trial which compared ASV to SIMV and studied a group of one hundred post-operative coronary artery bypass graft (CABG) surgery patients over a four-month period. The data showed that there was no difference between ASV and SIMV for length of time on the ventilator. However, results of the study demonstrated that ASV mode was safe and effective.

Yazdannik and colleagues [6] conducted a similar randomized control trial to compare ASV to SIMV in sixty-four post-operative CABG surgery patients and examined both the length of time for intubation as well as the length of stay at the hospital. The results showed that the ASV group had a significantly lower mechanical ventilation time compared to the SIMV group (4.83 hours versus 6.71 hours). The length of stay in the hospital was 140 hours for the ASV group,

and 145 hours for the SIMV group. The study concluded that ASV led to a decreased amount of time on the ventilator, and a small decrease in the length of stay in the hospital.

Tam and colleagues [7] published a randomized controlled unblinded study of fifty-two elective post-operative CABG surgery patients, the study compared two different strategies of ASV in weaning, a constant target minute ventilation versus decremental reduction of the target minute ventilation and examined the percent minute ventilation setting and weaning time. The results showed that the group in which there was a decremental weaning of the percent minute ventilation had a significant reduction of duration of intubation compared to the constant minute ventilation (225 minutes versus 423 respectively).

Lellouche and colleagues [8] conducted a randomized control trial of sixty patients comparing ASV to an ICU protocol created to wean post-operative cardiac surgery patients. Results of the study showed that ASV was safe and maintained the patient's ventilator settings in the optimal range 89% of the time versus 12% with the patients following the weaning protocol. Additionally, there was also a need for 148 interventions with the protocol weaned patients in comparison to 5 interventions with the ASV group.

Gruber and colleagues [9] compared ASV to pressure regulated volume control (PRVC) AutoMode. Fifty post-operative elective CABG patients were randomly assigned to either the ASV or AutoMode group. Weaning times to extubation were compared between the two modes. Results showed that ASV had a shorter ventilator time in comparison to AutoMode. On average, ASV patients were ventilated for 300 minutes as compared to 540 minutes on Automode.

Fathi and colleagues [10] compared weaning with ASV to PSV in 90 patients, post-operative CABG. In the ASV group, significantly higher numbers of patients were weaned from first trial, there was a shorter duration of weaning, mechanical ventilation, and ICU stay, with fewer manual ventilator adjustments and arterial blood gas (ABG) sample drawing during weaning. At extubation, this group showed a significantly lower respiratory rate, higher tidal volume, and lower peak airway pressure compared with the pressure support ventilation group.

Lastly, a recent study by De Bie [11] compared fully automated weaning by ASV versus conventional mechanical ventilation in 220 patients, post-operative CABG and found that ASV optimized lung-protective ventilation during postoperative ventilation, with fewer episodes of severe hypoxemia and an accelerated resumption of spontaneous breathing.

Other clinical conditions

In addition to the studies comparing ASV to alternative modes for post-cardiac surgery patients, there were two other studies [12,13] which compared weaning with ASV to alternative modes of ventilation. Summary of those studies are listed in Table 2.

Kirakli and colleagues [12] compared ASV to PSV for ninety-seven patients that had COPD over a period of twenty months. The study concluded that the weaning times were shorter using ASV (average of 24 hours with ASV versus 72 hours with PSV), but there was similar extubation success rate between both modes.

A study by Celi and colleagues [13] conducted a randomized controlled study on twenty post-operative liver transplant patients and compared ASV to SIMV with pressure support. The study assessed the duration of time ventilated and the number of manual setting changes. The results showed that there was a shorter duration of time ventilated for patients on ASV, 90 ± 13 minutes with ASV and 153 ± 22 minutes with SIMV. Ventilator setting modifications were more frequent with the SIMV group (6 ± 2) as compared to the ASV (5 ± 1).

Peak airway pressures were also noted to be higher in the passive SIMV group and the high-pressure alarms occurred more frequently. The study concluded that ASV is superior regarding weaning times as well as simplifying respiratory management.

A large Cochrane review and metanalysis [14] compared auto mated versus non automated modes for weaning critically ill adults and children. Though this study was not specific for ASV but included other automated modes, it is worth mentioning. The results showed that automated systems may reduce weaning, ventilation duration, and ICU stay.

Table 1. Summary of studies using ASV as a weaning mode for post-operative cardiac surgery patients.

Study	**Study Design**	**Objectives**	**Results**	**Conclusion**
Zhu F, et al [4] (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 [5] (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 [6] (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 [7] (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 [8] (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	Automated ventilation was safe for post-operative cardiac surgery patients providing an increased duration in optimal ventilation and reduced the number of interventions.

			than protocolized ventilation (5 vs 148 events).	
Gruber PC, et al [9] (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 [10] (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 [11] (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.

Table 2. Summary of studies comparing ASV as a weaning mode for non-post-operative cardiac surgery patients.

Study	**Study Design**	**Objectives**	**Results**	**Conclusion**
Kirakli C, et al [12] (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 [13](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.

ASV compared to conventional modes of ventilation in respiratory failure

Kirakli and colleagues [15] conducted a randomized controlled trial of 229 patients in medical ICU and studied the duration of time on the ventilator and compared ASV to pressure control ventilation. The results showed that the median mechanical ventilation duration until weaning, weaning duration, and total mechanical ventilation duration were significantly shorter in the ASV group. Patients in the ASV group required fewer total number of manual setting changes on the ventilator to reach the desired pH and $PaCO_2$ levels. The number of patients extubated successfully on the first attempt was significantly higher in the ASV group. Weaning success and mortality at day 28 were comparable between the two groups.

Another randomized controlled pilot study by Agarwal and colleagues [16] comparing volume control ventilation (VCV) to ASV in forty-eight patients with ARDS was conducted to look at the length of time on the ventilator and the length of time in the hospital. In addition, the study also looked at the ease of use for each mode, the number of ABGs that were required, amount of sedation required, and the mortality rates. The results of the study were that there were no significant statistical differences between the VCV and ASV groups in any of the values listed above.

A small study in ten patients with acute lung injury by Dongelmans and colleagues [17] compared ASV versus PCV. Their results showed that ASV delivers a lower respiratory rate and higher V_T combination. Pressure limitation does correct for the rise of V_T but leads to a decline in minute ventilation.

Iotti and colleagues [18] conducted a prospective multicenter trial comparing ASV to conventional VCV and PCV in eighty-eight patients in three groups (no lung disease, restrictive, and obstructive lung diseases). In comparison between ASV and conventional ventilation, results showed either similarities or minor differences. Except for excessive V_T in a few obstructed patients, all differences were in favor of ASV.

Ghodrati and colleagues [19] compared ASV and SIMV in the neurosurgical intensive care unit. The patients were intubated for decreased level of consciousness due to brain injury. Patients were hemodynamically stable with no serious respiratory disease. Sixty patients were alternated between ASV and SIMV. The results of the study showed that with ASV the respiratory dead space, peak inspiratory pressure, end-tidal carbon dioxide, and V_T were significantly lower. The lung compliance with ASV showed a non-significant improvement. The study concluded that ASV could lead to improved lung compliance and respiratory dead space.

El Shenawy and colleagues [20] randomized 60 patients with COPD to ASV versus SIMV with PSV. ASV provided shorter weaning times and a shorter hospital stay compared with SIMV + PSV. Similar weaning failure rates, death rate, and intubation period in both groups concluded that ASV mode was successful as a mode of initiation, maintenance, and weaning in acute exacerbation of patients with COPD.

Sehgal and colleagues [21] conducted a feasibility trial in seventy-four patients with acute COPD exacerbation and randomized them to non-invasive ventilation (NIV) using either PSV or ASV. There were no differences regarding NIV failure, mortality, or complications, concluding that the application of NIV using ASV was associated with a similar success rate as PSV in subjects with COPD exacerbation.

Dai and colleagues [22] examined the question if ASV can attenuate ventilator induced lung injury with fifteen patients with ARDS and eighteen pigs. They concluded that ASV mode can provide a ventilation pattern fitting of a lung-protecting strategy, and that ASV mode may effectively reduce the risk or severity of ventilator-associated lung injury in animal models.

A small animal study in pigs done by Jung and colleagues [23] compared ASV with spontaneous breathing to controlled mandatory ventilation with no spontaneous breathing. Their results showed that the transdiaphragmatic pressure decreased by 30% of its baseline value in the CMV group. Whereas it did not decrease in the ASV group. Additionally, CMV was associated with an atrophy of the diaphragm that was not detected in the ASV group.

A bench study using a lung simulator was conducted by Sulemanji and colleagues [24] to compare ASV to VCV in an ARDS model using V_T. The study focused on the pattern of ventilation to maintain ventilation without exceeding a plateau pressure of >28 cm H_2O. The simulator used six unique lung mechanics and scenarios with different lung compliance and resistance values with different set PEEP levels to simulate ARDS. The results were that ASV maintained a lower plateau pressure than the fixed V_T in the low lung compliance,

increased PEEP, and increased target minute volume scenarios. To maintain a safe plateau pressure, ASV does decrease V_T. The study recommends that further clinical trials are necessary to determine if the benefits of ASV will affect patient outcomes.

Table 3. Summary of studies comparing ASV to conventional modes of ventilation in patients with respiratory failure.

Study	Study Design	Objectives	Results	Conclusion
Kirakli C, et al [15] (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 [16] (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 [17] (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 [18] (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.
Ghodrati M, et al [19] (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	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	AS may lead to improved lung compliance and respiratory dead space compared to SIMV.

		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.	difference between ASV and SIMV modes but was slightly improved with ASV.	
El-Shenawy O et al [20] (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 [21] (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 [22] (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 [23] (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 [24] (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.

ASV Compared to Other Automated Modes

A survey study by Mireles-Cabodevila and colleagues [25] to clinicians compared ASV to Mid frequency ventilation with a computer-controlled algorithm in five different clinical scenarios. The conclusion of the study showed that the computer settings and the clinician settings were similar for only normal lung physiology, while settings differed in other scenarios. In the scenario with the ARDS patient, ASV chose a higher V_T, whereas in the morbid obesity patient ASV had selected a lower V_T than the clinicians. They concluded that there are differences and similarities among initial ventilator settings selected by humans and computers for various clinical scenarios. The ventilation outcomes are the result of the lung physiological characteristics and their interaction with the targeting scheme.

A bench study using a lung simulator by Morato and colleagues [26] compared ASV to mandatory rate ventilation and SmartCare modes in six clinical scenarios. Their results showed that all three modes were equally able to recognize weaning success and failure, despite the presence of anxiety or irregular breathing but performed incorrectly in the presence of Cheyne-Stokes. Pressure support behavior over time differs among modes, with ASV showing larger and more frequent PS oscillations over time.

Table 4. Summary of studies comparing ASV to other automated modes.

Study	Study Design	Objectives	Results	Conclusion
Mireles-Cabodevila, E, et al [25] (2012)	Survey study to clinicians.	Comparison of ASV and Mid frequency ventilation (computer-controlled algorithm) to clinician selected settings in five different clinical scenarios.	Clinician selected tidal volumes were similar to the ASV setting (clinician: 6.1 – 8.3 mL/kg, ASV: 6.7 - 11.9 mL/kg, MFV: 3.5 - 9.9 mL/kg). The exceptions were with ARDS patient, ASV chose a higher V_T, whereas in the morbid obesity patient ASV had selected a lower V_T than the clinicians.	The conclusion of the study showed that the computer settings and the clinician settings were similar for only normal lung physiology, while settings differed in other scenarios
Morato, J, et al [26] (2012)	Bench study with lung simulator.	Comparison of ASV, mandatory rate ventilation (MRV), and SmartCare.	ASV, MRV and SmartCare were able to correctly recognize weaning success and failure with anxiety and irregular breathing, except for Cheyne-Stokes respirations. ASV had shorter time to PS stabilization (1-2 minutes vs MRV: 1-7 minutes, SmartCare: 8-78 minutes), and had higher rates of PS oscillations per 5 minutes (4-15 vs MRV: 0-12, SmartCare: 0-1), except with extreme anxiety.	ASV, SmartCare, and MRV can recognize weaning success and failure, with the exception of Cheyne-Stokes respirations.

Discussion

Is the ASV mode effective for weaning patients?

The literature review suggests that ASV is not inferior or may be even superior to other modes in weaning patients post-operatively and in other broad ranges of medical illnesses. (higher extubation success rates, and reduced ventilator length of stay) than clinician settings, protocols, or other modes of ventilation.

Is ASV a safe mode of ventilation for patients with chronic obstructive pulmonary disease (COPD) and acute respiratory distress syndrome (ARDS)?

Most of the studies demonstrated safe manipulations to ventilator settings by the ventilator in ASV. The studies in COPD concluded that ASV could significantly improve clinical outcomes and selects low rates, larger VT with long exhalation times as compared to conventional ventilation modes.

The studies looking at patients with ARDS showed that ASV decreased the VT and increased the respiratory rate and was better able to prevent the potentially damaging effects of excessive plateau pressures. This literature review concludes that ASV was shown to be safe for ventilating patients with COPD and ARDS.

Is ASV a safe mode of ventilation with changes in lung dynamics?

The studies utilizing lung simulators to compare ASV to other automated modes and conventional modes. Different lung conditions and respiratory efforts were simulated, and the different modes were compared. The results of the literature review show that ASV made similar ventilator changes as a human clinician, and in support of ASV being a safe mode of ventilation in these patient populations.

Does ASV impact the bedside respiratory therapist?

The benefits identified were the decrease in the number of changes required by the respiratory therapist, earlier recognition of patient's readiness for extubation, and a high success rate once extubated. Another potential benefit for bedside Respiratory Therapists were fewer high-pressure alarms. All these factors, fewer nuisance alarms and fewer ventilator changes could help to free up the therapist's time and may also increase the time available for patient care.

Conclusion

ASV is not a new mode of ventilation, but it has not been studied in many clinical trials. Most of the studies concluded that more clinical trials are necessary to validate the findings.

The data collected and reviewed from the research concludes that ASV was safe to use.

ASV has shown to make the appropriate changes to ventilator settings with changes in patients' lung dynamics. ASV can reduce the time a patient requires ventilator support, while using lung protective strategies such as reducing peak airway pressures. ASV reduces the respiratory rate and increases VT to extend expiratory time with COPD patients, reducing air-trapping.

ASV decreases VT and increases respiratory rates to maintain minute ventilation in patients with ARDS. ASV may show difficulty with maintaining minute ventilation of a very stiff lung, as it shows to decrease VT and increase respiratory rates when the compliance worsens. With these types of patients, other strategies may be more beneficial.

ASV can help the respiratory therapist with lung dynamic information and measurements. This can aid the respiratory therapist in making appropriate changes to the ventilator settings. Fewer triggering of the ventilator alarms, the ventilator automation of changing settings appropriately may lead to additional time spent with the patient. Thus, time can be provided to improve the quality of care for the patient. ASV does not take away the need for a respiratory therapist. ASV must be set up and monitored by a clinical specialist to ensure safe ventilation of the patient.

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