Original Article

A Prospective Randomized Comparison of INTELLIVENT-ASV and PSV Modes in Terms of Weaning in Intensive Care Patients, Istanbul, Turkiye

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Abstract

Background: INTELLIVENT-Adaptive Support Ventilation (I-ASV; C6; Hamilton Medical; Bonaduz, Switzerland) is a closed-loop ventilation mode that continuously controls the patient's ventilation and oxygenation. It sets the minute ventilation, PEEP, and oxygen levels based on the targets set by the clinician and on physiological input from the patient. **Aim:** The aim was to compare I-ASV and PSV modes regarding weaning in intensive care patients. **Methods:** A total of 140 patients who were over the age of 18 years, did not have a neuromuscular disease, and had been ventilated for at least 48 hours were reviewed. Using the sequential method, patients who met the requirements for weaning were put into two groups: I-ASV and PSV (pressure support ventilation). **Results:** The mean age of the I-ASV group (n = 70) and the PSV group (n = 70) was 49.11 ± 17.74 and 49.92 ± 22.00, respectively. In the group using I-ASV, FiO_2 was 30.12 ± 10.04%, inspiratory pressure (Pinsp) was 8.71 ± 2.78 cm H_2O, and Ppeak value was 11.67 ± 2.78 cm H_2O, which were significantly lower than those in the PSV mode ($P < 0.001$). The PEEP value was significantly lower in the PSV mode ($P < 0.001$). However, asynchrony-tachycardia was significantly higher in the I-ASV group (28 (20%)) compared to the PSV group (11 (7.9%)) ($P < 0.003$). **Conclusion:** I-ASV mode had no effect on weaning duration compared to PSV mode but decreased PEEP, FiO_2, Pinsp, and Ppeak values in weaning patients.

Keywords: *INTELLIVENT adaptive support ventilation, pressure support ventilation, weaning*

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Introduction

INTELLIVENT-Adaptive Support Ventilation (I-ASV; C6; Hamilton Medical, Bonaduz, Switzerland) is a closed-loop ventilation mode that continuously controls the patient's ventilation and oxygenation. It sets the minute ventilation, PEEP, and oxygen levels based on the targets set by the clinician and on physiological input from the patient. I-ASV also provides tools to promote early, automated weaning. Hamilton-C6 represents a new generation of high-end ventilators. It uses end-tidal carbon dioxide ($ETCO_2$), respiratory rate, and arterial oxygen saturation (measured via the pulse) to automatically modulate inspiratory oxygen fraction (FiO_2), percent ventilation per minute, and positive end-expiratory pressure (PEEP). The ASV algorithm is based on minimum work and respiratory force, which are related to minimum inspiratory pressure and tidal volume.[1] To reach a target peripheral oxygen saturation (SpO_2) and avoid hyperoxygenation, the oxygenation parameters FiO_2 and PEEP are automatically adjusted. Numerous studies have shown I-ASV to be beneficial, although its effects on the weaning process are still not completely understood.[2–7] In this study, we weaned patients who were followed up in intensive care and were suitable for weaning, either with I-ASV or PSV mode. The purpose of this research is to evaluate the effect and effectiveness of the I-ASV mode on weaning compared to PSV.

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Materials and Methods

This study was a prospective, randomized study that was conducted in Başakşehir Çam and Sakura Training and Research Hospital between June 1, 2022 and February 28, 2023.

The sample size was calculated using the G-Power 3.1 program, assuming an effect size of 1 and an alpha error of 0.05 for the means: the difference between two independent means (two groups) model, the minimum number of patients that needed to be included to reach 95% working power was found to be 46.[5]

The criteria for inclusion in this study were the absence of chronic lung disease and a Glasgow Coma Score (GCS) score of >12 during weaning. The exclusion criteria were age of <18 years, diagnosis of lung cancer and/or having undergone space-occupying lesion surgery, pregnancy, a history of organ transplantation and/or the use of immunosuppressive drugs, a GCS score of ≤12, failure to meet the criteria for weaning, history of tracheostomy, and <48 hours following weaning [Figure 1].

A total of 140 patients (informed consent was gathered from either the patients or their relatives) who were over the age of 18 years, did not have a neuromuscular disease, and had been ventilated for at least 48 hours were reviewed. When the patients were intubated in the intensive care unit (ICU), they were all monitored in pressure-supported synchronized intermittent mandatory ventilation (P-SIMV) mode. Patients who satisfied the weaning requirements were identified using the sequential method and divided into the I-ASV group and the pressure support ventilation (PSV) group. Patients with tracheostomies were not included in the study. Age, gender, diagnosis of disease, other underlying diseases, number of days on mechanical ventilation, length of stay (LOS) in the ICU, length of stay in the hospital, blood gas results on the day of weaning, mechanical ventilation settings and values, complete blood count, kidney function tests (urea and creatinine), liver function tests (ALT and AST), coagulation values, and C-reactive protein (CRP) and procalcitonin (PRC) values were recorded. The patients' acute physiology, chronic health assessment (APACHE) score, and sequential organ failure assessment score (SOFA) were calculated on the day of admittance to the ICU. Throughout the process of weaning, a daily record was kept of whether the ventilator mode was altered during shift changes. During the course of each patient's follow-up care, the following questions were posed on a daily basis to the nurses who monitored the patient's condition:

1) Did I-ASV patient monitoring increase your workload?
2) Did observing the patient in a PSV increase your workload?

All nurses who were in charge of a certain patient had to answer yes or no to the questions above. The result was determined by the response with the highest percentage. Patients who met the following criteria were successfully weaned: recovery from underlying disease, absence of fever, PaO_2 >90%, FiO_2 requirement < 40% and PEEP < 8, hemodynamic stability (no vasopressors), readiness to return to spontaneous ventilation, adequate level of consciousness (awake or easily awakened), and a pH of 7.35.

Rapid shallow breathing index (RSBI), defined as the ratio of breathing frequency to average tidal volume in 1 min (breaths/min/L), has been shown to be one of the most accurate predictors of weaning outcome.[8]

INTELLIVENT–ASV

The I–ASV automatically adjusts and applies almost all ventilator settings that are typically adjusted or set by physicians.[9–13] It also constantly adjusts the minute volume based on continuous ($ETCO_2$) readings. PEEP and FiO_2 titrations are continuously adjusted based on continuous SpO_2 readings: To do this, the I-ASV uses the ARDS Network PEEP–FiO_2 tables.[14] The target ranges for $ETCO_2$ and SpO_2 are set by the operator, in part by choosing a lung disorder (acute respiratory distress syndrome or chronic obstructive pulmonary disease) or a patient condition (brain injury), if present or applicable. I-ASV facilitates weaning by gradually reducing minute volume and can be set to use a spontaneous breathing trial by progressively reducing the ventilator settings within predefined limits, allowing for the timely identification of patients who are ready to be extubated. During continuous $ETCO_2$ and SpO_2 measurements, patients are monitored for asynchrony-tachycardia as well as technique and patient-related causes.

Pressure support ventilation (PSV) is a type of positive pressure mechanical ventilation that allows the patient to initiate each breath. PSV can be administered with endotracheal tube-based (invasive) mechanical ventilation. It is the most comfortable form of ventilation for patients and is useful for weaning them off invasive ventilation. Flow (L/min) delivery is accomplished by establishing a driving pressure (cmH_2O). The delivered flow depends on the set driving pressure, airway resistance, lung compliance, and the patient's inspiratory effort. The breath is flow-limited, which means that the driving pressure ceases when the flow falls to a predetermined percentage (usually 25%) of the peak flow. The delivered tidal volume (mL) depends on the flow and duration of the inspiratory phase. PSV mode settings include driving pressure, PEEP, and FiO_2. Patients' minute ventilation (L/min) is determined by their respiratory rate and the tidal volume of each

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breath. In PSV, there are no required breaths; thus, there is no minimum minute ventilation.[15] This mode is used to monitor patients for asynchrony-tachycardia.

Ethical consideration

This study was approved by the Ethics Committee of Istanbul Başakşehir Çam and Sakura Training and Research Hospital on May 25, 2022, with the number KAEK/2022.05.172. Informed consent was obtained from first-degree relatives and/or legal guardians. Each patient participating in the study was given a sequential number other than the hospital file number.

Statistical analysis

IBM SPSS Statistics 25 was used for data entry and statistical analysis. One-sample Kolmogorov-Smirnov test was used to determine the distribution of the data. Quantitative variables were expressed as mean and standard deviation or median (interquartile range) based on their distribution. Numbers and percentages were used to represent categorical variables. For continuous data with normal distribution, the student *t*-test was performed, and for those that were skewed, the Mann-Whitney U test was used. The Chi-square test was performed to compare categorical data between two groups. *P* value < 0.05 was taken as significant.

Results

There were 140 participants in the study. Table 1 summarizes the clinical characteristics of the patients. The mean age of the I-ASV group (n = 70) was 49.11 ± 17.74 years, while the mean age of the PSV group (n = 70) was 49.92 ± 22.00 years. Forty-four (31.4%) of these 140 patients required ICU follow-up in the postoperative period, 61 (43.6%) needed it due to sepsis, and 39 (27.85%) required it for other reasons (acute renal failure, diabetic ketoacidosis, status epilepticus, and trauma). In the group using I-ASV, FiO_2 was 30.2 ± 10.04%, inspiratory pressure (Pinsp) was 8.71 ± 2.78 cm H_2O, and peak pressure (Ppeak) was 11.67 ± 2.78 cm H_2O, which were significantly lower than those in the PSV mode ($P < 0.000$). Again, the PEE*P* value was 5.14 ± 0.35 cm H_2O, which was statistically significant ($P < 0.001$) and lower than that in the PSV mode [Table 2]. However, in the I-ASV group, asynchrony-tachycardia was observed in 28 (20%) patients ($P < 0.003$), and an increase in nurse workload was observed in 36 (25.7%) ($P < 0.000$) patients. Due to a lack of experience with I-ASV mode during shift changes, a desire to change the mechanical ventilator mode in 33 patients (23.6%) was detected ($P < 0.01$). In such cases, the operator was contacted by the study

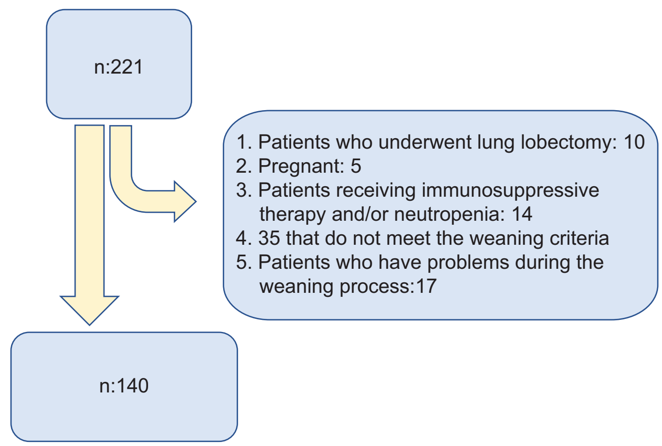

Figure 1: Flow diagram

Table 1: Demographic data and clinical characteristics of patients (*n*=140)

	All (*n*=140) *n* (%) Mean±SD	ASV group (*n*=70) *n* (%) Mean±SD	PSV group (*n*=70) *n* (%) Mean±SD	*P*
Reintubation	34 (24.3%)	20 (14.3%)	14 (10.0%)	0.32
Gender (male)	69 (49.3%)	47 (33.6%)	22 (15.7%)	<0.001
Age (years)	49.11±19.93	49.30±17.74	49.92±22.00	0.63
Hypertension	44 (31.4%)	20 (14.3%)	24 (17.1%)	0.58
Coronary artery disease	26 (18.6%)	12 (8.6%)	14 (10.0%)	0.82
Diabetes mellitus	35 (25.0%)	16 (11.4%)	19 (13.6%)	0.69
Hyperlipidemia	29 (20.7%)	14 (10%)	15 (10.7%)	1.00
Malignancy	25 (17.9%)	12 (8.6%)	13 (9.3%)	1.00
Admission reasons				
• Postoperative	44 (31.4%)	20 (14.3%)	24 (17.1%)	0.58
• Sepsis	61 (43.6%)	29 (20.7%)	32 (22.9%)	0.60
• Other	39 (27.9%)	21 (15%)	18 (12.9%)	0.70
LOS in ICU in days	20.88±10.06	18.27±10.13	23.50±9.35	0.002
LOS in hospital in days	28.4±16.43	26.95±15.53	29.88±17.28	0.29
Duration of MV in days	8.15±4.07	8.55±4.31	7.74±3.8	0.23
NIV (hours post extubation)	44 (31.4%)	23 (16.4%)	21 (15%)	0.85

LOS: length of stay; ICU: Intensive care unit

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Table 2: Mechanical ventilator values and scoring in the weaning process

	All (n=140) Mean±SD/ Median (IQR)	I-ASV group (n=70) Mean±SD/Median (IQR)	PSV group (n=70) Mean±SD/Median (IQR)	P
FiO_2 (%)	30.94±1.97	30.12±10.04	31.71±2.3	0.000
Expiratory minute volume (L/min)	10.18±1.79	9.92±2.21	10.45±1.17	0.25
Tidal volume (mL)	549.21±130.8	546.61±163.67	551.94±85.13	0.08
Respiratory rate/min	17.21±4.65	17.42±6.18	19.98±2.16	0.18
PEEP (cm H_2O)	5.56±1.11	5.14±0.35	5.98±1.41	0.00
Pinsp (cm H_2O)	9.64±2.57	8.71±2.78	10.62±1.91	0.000
RSBI	48.81±17.07	52.07±19.08	45.41±14.03	0.007
PH	7.47±0.03	7.47±0.45	7.46±0.02	0.71
PaO_2 mmHg	96.87±10.87	97.32±11.57	96.41±10.19	0.6
$PaCO_2$ mmHg	37.82±4.53	37.7±11.8	37.93±3.01	0.13
Lactate	1.1 (0.5–1.7)	1.1 (0.5–1.7)	1.1 (0.9–1.3)	0.59
PPeak (cm H_2O)	13.01±2.8	11.67±2.25	14.35±2.69	0.000
Weaning (hours)	31.95±9.22	32.6±7.2	32.85±9.3	0.84
Reintubation (days)	3.85±1.28	3.8±1.36	3.9±1.2	0.76
APACHE II	12.3±2.8	11.94±2,37	12.65±3.16	0.94
SOFA (admission)	5.87±1.38	5.67±1.62	6.07±1.067	0.07
SOFA (at extubation time)	2.81±1.50	2.7±1.57	2.94±1.43	0.56
GCS	14.17±0.80	14.22±0.8	14.12±0.81	0.46

I-ASV: INTELIVENT ADAPTIVE SUPPORT VENTILATION group, PSV: PRESSURE SUPPORT VENTILATION group; FiO_2: inspiratory oxygen fraction; PEEP: positive end-expiratory pressure; Pinsp: Inspiratory pressure; RSBI: Rapid shallow breathing index; $PaCO_2$: Partial pressure of carbon dioxide; $ETCO_2$: End-tidal carbon dioxide, PaO_2: Partial pressure of oxygen; TV: Tidal volume; APACHE: Acute Physiology and Chronic Health Evaluation; SOFA: Sequential organ failure assessment score, MV: Mechanical ventilation, GCS: Glasgow Coma Scale score

Table 3: Problems during the weaning process

	All (n=140)	I-ASV group (n=70)	PSV group (n=70)	P
Asynchrony-tachycardia	39 (27.9%)	28 (20%)	11 (7.9%)	0.003
Nurse workload	51 (36.4%)	36 (25.7%)	15 (10.7%)	<0.001
Mode change	50 (35.7%)	33 (23.6%)	17 (12.1%)	0.01

team, and the problem was resolved by the team. This rate was higher for I-ASV (P < 0.01). Asynchrony and tachycardia were observed in 11 (7.9%) patients in the PSV group. Mode change was detected in 17 (12.11%) patients. Fifteen nurses (10.7%) reported that their workload was higher with the PSV mode. Table 3 summarizes the problems encountered during weaning. In addition, sensor issues were detected in the I-ASV mode in 35 (25%) patients. In the I-ASV group, weaning occurred at a rate of 32.6 ± 7.22/h, while in the PSV group, weaning occurred at a rate of 32.85 ± 9.38/h (P = 0.84). The number of days for which mechanical ventilation was required was 8.55 ± 4.31 days in the I-ASV group and 7.74 ± 3.8 days in the PSV group, which was shorter (P = 0.002). In the I-ASV group, the length of stay (LOS) in the intensive care unit (ICU) was 18.27 ± 10.13 days, and the LOS in the hospital was 26.95 ± 15.53 days; thus, LOS in the ICU was shorter in the I-ASV group than in the PSV group (P = 0.002). Moreover, 47 (33.6%) of I-ASV cases and 22 (15.7%) of PSV cases were male (P < 0.000). Also, Table 4 shows the laboratory values of the patients at the time of hospitalization.

Discussion

The primary objective of this study was to evaluate weaning time, tidal volume, Pinsp, Ppeak, and FiO_2 level required in MV for I-ASV weaning. In our study, weaning time and tidal volume values for I-ASV and PSV modes were comparable. However, we discovered that the peak values of PEEP, FiO_2, and Pinsp in I-ASV were lower than in patients weaned from PSV mode.

Closed-loop ventilation modes that automatically adjust mechanical ventilation settings based on physiological input[12] aim to select personalized ventilation,[16] reduce workload,[17] enhance patient-ventilator synchrony,[18] and shorten weaning time.[19,20] We found no distinctions between I-ASV and PSV's weaning times in our study. In the I-ASV group, there were 36 (25.7%) patients with sensory issues and accompanying issues such as asynchrony-tachycardia. According to the nurses caring for these patients, their workload increased during the I-ASV mode weaning process. In a study comparing I-ASV and PSV modes, it was found that I-ASV was associated with a higher PaO_2/FiO_2 ratio and a greater coefficient of variation for Pinsp and PEEP.[4] In our investigation, PEEP, FiO_2, tidal volume, Pinsp, and Ppeak values were lower in the I-ASV mode group than in the PSV mode group.

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Table 4: Laboratory values of the patients at admission

	All (*n*-140) Mean±SD/ Median (IQR)	I-ASV group (*n*=70) Mean±SD/Median (IQR)	PSV group (*n*=70) Mean±SD/Median (IQR)	*P*
WBC (10^9/L)	8.25±2.5	8.42±2.49	8.07±2.51	0.41
HB (10^9/L)	8.84±0.95	8.91±0.78	8.77±0.84	0.36
Platelet (10^9/L)	262.22±120.90	270.46±119.75	253.98±122.33	0.80
Glucose (mg/dL)	174.9±60.69	164.71±48.30	185.08±69.83	0.47
BUN (mg/dL)	48.35±28,50	36.77±12.42	59.93±34.78	0.00
Creatinine (mg/dL)	0.45±0.21	0.54±0.12	0.36±0.24	0.00
Na (mEq/L)	137.88±3.01	137.88±3.28	138.42±2.72	0.28
K (mEq/L)	3.76±0.22	3.8±0.2	3.81±0.22	0.84
AST (U/L)	44 (32.75–55.25)	44 (26.25–61.75)	43 (34.13–51.87)	0.60
ALT (U/L)	38 (22.95–53.05)	34 (14.63–53,37)	48 (15.5–80.5	0.06
PTZ (s)	9.98±0.96	9.99±1,14	9.98±0.73	0.93
INR	1.12±0.12	1.13±0.14	1.10±0.33	0.32
CRP (mg/L)	53,62±18.24	63.64±18,24	51.64±17.50	0.51
PCT (ng/mL)	0.31±0.16	0.32±0.17	0.35±0.18	0.33

WBC: White blood cell, HB: hemoglobin, BUN: Blood urea nitrogen, AST: Aspartate transaminase, ALT: Alanine aminotransferase, PTZ: Prothrombin time, CRP: C-reactive protein, PCT: Procalcitonin, IQR: Interquartile range

Concerning tidal volume and PEEP, numerous studies on I-ASV have produced contradictory results. Studies examining tidal volumes have found lower,[2,5,22] higher,[4] or equivalent[7,22,23] tidal volumes. Again, with regard to PEEP, different studies have determined high, normal, and low PEE*P* values.[4,5,7,22-24] In this study, there was no significant difference between the I-ASV and PSV groups' tidal volumes. However, the I-ASV group had lower PEE*P* values. This lower PEE*P* value may be because weaning was evaluated in this study, and patients with PaO_2 > 90 and FiO_2 requirements of 40% were included in the study. In addition, as SpO_2 and $ETCO_2$ were continuously monitored simultaneously in the I-ASV group's mechanical ventilator, the decrease in ventilation parameters between the adjusted values may explain this finding. In this study, the I-ASV group had lower PEEP, Pinsp, P peak, and FiO_2 levels. However, PaO_2 values were comparable between the two groups. In the study of Anan'ev EP and colleagues, they reported that there was no difference in $ETCO_2$ and CO_2 parameters between P-CMV and I-ASV modes.[21] As SpO_2 and $ETCO_2$ were monitored simultaneously and continuously in I-ASVs, when the desired SpO_2 and $ETCO_2$ values were attained or exceeded, the percentage of PEEP and FiO_2 minute mechanical ventilation decreased automatically. While a lower FiO_2[2,5,22] was used in some I-ASV studies, other studies indicate that a similar FiO_2 was used.[4,7,24]

The I-ASV group had sensor problems with multiple asynchronous tachycardias. Inaccurate measurements from cold extremities or challenges with the sensor coming into contact with the finger were possible causes of the sensor problem. The desire to change the I-ASV mode to another mode was greater during shift changes. We observed that the lack of experience with this mode is the reason for this. It was difficult for the patient to adapt to ventilation due to the automatic adjustment of ventilation settings based on inaccurate $ETCO_2$ and SpO_2 results, and sensor problems increased the nurse's workload. When the saturation is measured to be low due to factors such as insufficient sensor contact or a cold extremity, the ventilator increases the PEEP and minute ventilation percentage to reach the target value. In addition, when the sensor comes out of the finger in this mode, it continues to ventilate automatically based on the most recent SpO_2 and $ETCO_2$ measurements. Obviously, in all of these situations, the mechanical ventilator's alarm is activated and the employee is warned. This made the weaning process difficult for patients who were conscious and were about to be weaned. In instances where such technical difficulties were not encountered, the patient tolerated it better, and there were no challenges during weaning. It was also apparent that doctors and nurses prefer to monitor patients in more experienced modes as opposed to ventilator mode, where they have less experience.

When utilizing automatic ventilation modes such as I–ASV, the SpO_2 and $ETCO_2$ target ranges must be determined and measured accurately. This is very different from how manual modes are utilized. Healthcare professionals may experience an increase in workload rather than convenience as a consequence of this circumstance. Therefore, it is understandable that experienced healthcare professionals would resist automated modes such as I–ASV.

The I-ASV group was only observed in this manner during the weaning process. Our study is limited by the fact that I-ASV was not administered following the initiation of mechanical ventilation. Therefore, it is impossible to comment on the effects of LOS in the ICU, LOS in the hospital, or the number of days of mechanical ventilation. In future studies, utilizing I-ASV from the onset of treatment will provide more useful information.

As a result, I-ASV mode had no effect on weaning duration compared to PSV mode but decreased PEEP, FiO_2, Pinsp, and Ppeak values in weaning patients. The technical difficulties experienced in I-ASV, especially erroneous measurements in $ETCO_2$ and SpO_2, increased the number of alarms and therefore the nurse workload. It has also been observed that the operator's inexperience in this mode limits the use of this mode.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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