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Original Article

Effects of Modes, Obesity, and Body Position on Non-invasive Positive Pressure Ventilation Success in the Intensive Care Unit: A Randomized Controlled Study

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Abstract

OBJECTIVES: Different outcomes and success rates of non-invasive positive pressure ventilation (NPPV) in patients with acute hypercapnic respiratory failure (AHRF) still pose a significant problem in intensive care units. Previous studies investigating different modes, body positioning, and obesity-associated hypoventilation in patients with chronic respiratory failure showed that these factors may affect ventilator mechanics to achieve a better minute ventilation. This study tried to compare pressure support (BiPAP-S) and average volume targeted pressure support (AVAPS-S) modes in patients with acute or acute-on-chronic hypercapnic respiratory failure. In addition, short-term effects of body position and obesity within both modes were analyzed.

MATERIAL and METHODS: We conducted a randomized controlled study in a 7-bed intensive care unit. The course of blood gas analysis and differences in ventilation variables were compared between BiPAP-S (n=33) and AVAPS-S (n=29), and between semi-recumbent and lateral positions in both modes.

RESULTS: No difference was found in the length of hospital stay and the course of PaCO2, pH, and HCO3 levels between the modes. There was a mean reduction of 5.7±4.1 mmHg in the PaCO2 levels in the AVAPS-S mode, and 2.7±2.3 mmHg in the BiPAP-S mode per session ($p<0.05$). Obesity didn't have any effect on the course of PaCO2 in both the modes. Body positioning had no notable effect in both modes.

CONCLUSION: Although the decrease in the PaCO2 levels in the AVAPS-S mode per session was remarkably high, the course was similar in both modes. Furthermore, obesity and body positioning had no prominent effect on the PaCO2 response and ventilator mechanics. Post hoc power analysis showed that the sample size was not adequate to detect a significant difference between the modes.

KEYWORDS: acute respiratory failure, non-invasive mechanical ventilation, pressure support, bilevel, AVAPS

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INTRODUCTION

Most of the patients admitted to intensive care units (ICUs) have respiratory failure accompanied by hypercapnia in majority of cases. The aim of the ventilatory support in these patients is to support respiratory muscles until the underlying deterioration is resolved, to improve reduced ventilation, arterial oxygen, carbon dioxide levels, and acidosis [1,2]. Non-invasive positive pressure ventilation (NPPV) has been considered as one of the most important developments in the field of pulmonology since it eliminates the complications associated with invasive mechanical ventilation [3].

Different outcomes and success rates observed in case of NPPV in patients with acute hypercapnic respiratory failure (AHRF) raise the question of what are the factors that lead to success. Previous studies investigating body positioning and obesity-associated hypoventilation in patients undergoing NPPV showed that these factors may affect inspiratory and expiratory pressures to achieve a better minute ventilation (MV) [4-6]. Patient's comfort and adherence can be improved with the appropriate use of NPPV [7,8]. For an effective NPPV, an adequate MV should be sustained after selecting an appropriate mode; air leaks in the circuit should be minimized; and the patient–ventilator synchrony must be optimized [9,10]. When NPPV is administered using the pressure support (spontaneous bilevel pressure ventilation; BiPAP-S) mode, patient receives a respiratory support of specified constant inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). This type of constant pressure can be affected by the resistance changes in the circuit, and it may not adapt to the varying needs of the patient. In

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the average volume assured pressure support (AVAPS-S; AVAPS®) mode, which can be defined as a volume-targeted variable pressure support, IPAP values are adjusted by the device at previously specified intervals, based on the needs of the patient, to achieve the specified tidal volume target [11,12]. Thus, it seems that AVAPS-S mode should allow a more constant MV, not affected by the resistance changes in the circuit. However, in acute settings, there are no data comparing both the modes, and the effects of patient body position and obesity on success rate are unknown.

The present study was primarily designed to compare the outcomes of the BiPAP-S and AVAPS-S modes in patients with acute or acute-on-chronic hypercapnic respiratory failure who were admitted to an ICU. Secondary objectives were to determine the effect of obesity on the course of carbon dioxide response and evaluate the short-term effects of body positioning during the therapy on the ventilation variables and $PaCO_2$ response. Any results that will be obtained by determining the effects of two different modes and body positioning during NPPV will guide us on how to administer NPPV in patients with AHRF. Thus, it will enhance the efficacy of NPPV in AHRF and lead to reductions in the length of stay in ICUs and treatment costs.

MATERIAL AND METHODS

The study was approved by the Gazi University Clinical Research Ethics Committee (Date 06/15/2011, Decision No 226). The patients were informed about the study, and all provided a written letter of consent.

Patient Selection

This single-blind randomized controlled study was carried out between June 2011 and December 2013 in a 7-bed adult ICU of a university hospital experienced in NPPV. The study included adult patients who were diagnosed with acute or acute-on-chronic hypercapnic respiratory failure, had $SpO_2 \leq 90\%$ and $PaCO_2 \geq 55$mmHg in blood gas analysis, and were scheduled for non-invasive mechanical ventilation. Patients with any anatomical problem that might have interfered with mask ventilation, those at the terminal stage of their disease, those who experienced loss of consciousness or clinical unstabilization at any time during follow-up (shock, need for vasopressor support, Glasgow Coma Scale<10, required endotracheal intubation), and those who couldn't remain in the semi-recumbent or lateral position for a long time were excluded.

Study Design

Two identical ventilators (Respironics-TRILOGY© S-100; Respironics Inc; Murrysville, PA) were used in the study. The most appropriate mask was chosen for each patient among three different sizes of orinasal masks with the same features. Each patient received BiPAP-S therapy (IPAP of 15 cmH_2O, and EPAP of 5 cmH_2O at an angle of 30°-45° in semi-recumbent position), with supplemental oxygen therapy adjusted to achieve SO_2 90%-95%, for 1 hour to maintain clinical stability after obtaining blood gas analysis at admission. Following this 1-hour NPPV therapy, patients were randomized to receive non-invasive mechanical ventilation either via BiPAP-S mode or AVAPS-S mode. Randomization was stratified by body mass index (<30 kg/m2, ≥30 kg/m^2). Patients received NPPV, including nights, and each session lasted for at least 2 hours. The duration of NPPV application was maximized in the first 48 hours and gradually reduced according to general improvements in patient's condition and blood gas analysis. Due to high number of patients with chronic respiratory failure, the decision on NPPV discontinuation did not solely depend on $PaCO_2$ levels in the patients. Blood gases were monitored before and after each NPPV session. Measurements were regularly followed for each patient throughout the study using a software (DirectView version 1.4.2; Koninklijke Philips Electronics N.V.). Each patient received supplemental oxygen to achieve SO_2 90%-95% if needed, and no changes were made to other treatment regimens. Factors influencing the treatment failure during NPPV were not the subject of this study.

Alignments and Validation

For BiPAP-S mode, IPAP was set and titrated daily to provide tidal volume (VT) calculated from 8 mL/kg, based on ideal body weight during wakefulness, and EPAP was set to provide optimal airway patency by keeping apnea at minimum during monitoring. For AVAPS-S mode, $IPAP_{max}$ was set at 30 cmH_2O, and $IPAP_{min}$ was set 4 cmH_2O greater than the EPAP value, which would keep apnea at minimum during monitoring. VT was set to provide the target of 8 mL/kg of the ideal body weight. During non-invasive mechanical ventilation, end tidal CO_2 levels and tidal volumes were recorded in some patients using capnography (CO2SMO Plus) to confirm the accuracy of volumes obtained by the devices.

Body Positioning

Two different positions, semi-recumbent and lateral (at an angle of 15°-45° and 0°-15°, respectively) were used during daytime throughout the monitoring period to evaluate the short-term effects of body positioning during NPPV. After randomization to two different modes, each patient was treated alternately in semi-recumbent and lateral positions, during equal treatment periods.

Measurements

All patients underwent pulmonary function tests, echocardiography, and body mass index evaluation. pH, PaO_2, $PaCO_2$, SaO_2, and HCO_3 were assessed for blood gas analysis, and MV, respiratory rate (RR), peak inspiratory pressure (PIP), and air leak were assessed for ventilation variables. The mean values were obtained for ventilation variables during each NPPV session. For primary outcome parameters, the mean of all daily results for blood gas analysis and ventilation variables was calculated. To evaluate short-term effects of body position, the mean of all semi-recumbent and lateral sessions' ventilation variables, and mean reduction in $PaCO_2$ level per session, was calculated and compared.

Outcomes

The primary endpoints of the study were the length of ICU stay and the overall course of PaCO2. Secondary endpoints included the effects of obesity on the course of $PaCO_2$ response, and body positioning on the ventilation variables and $PaCO_2$ response.

Statistical Analysis

Data were entered into Statistical Package for Social Sciences software version 17.0 (SPSS Inc.; Chicago, IL, USA), and analyses were made using the same software program. Kolmogorov-Smirnov test was used to compute the distribution of numerical variables, and those with a normal distribution were presented as mean ± standard deviation (SD). Repeated measures analysis of variance (ANOVA) was used to demonstrate the effect of selected mode on $PaCO_2$, HCO_3, and pH measurements. Only the first 6 days' variables were used for this comparison in order not to lose subjects. While comparing the effect of body positioning on the reduction in $PaCO_2$, the difference between pre- and post-therapy $PaCO_2$ measurements for each NPPV session was obtained, and the paired sample t-test was used to observe the differences in semi-recumbent and lateral positions in each mode. Independent-samples t-test was used for comparison between the two modes. p value of <0.05 was considered significant.

RESULTS

A total of 154 patients were included in the study during the period of 2 years, and 62 eligible patients completed the study (Figure 1). Of these 62 patients, 33 were randomized into the BiPAP-S mode, and 29 into the AVAPS-S mode. The demographic characteristics, APACHE-II scores, and comorbidities of both the groups are shown in Table 1. There were no significant differences between the baseline blood gas parameters at admission (Table 2).

The mean length of ICU stay was 7.4±2.6 days, and 8.4±3.2 days in the BiPAP-S and AVAPS-S modes, respectively (p=0.17). The mean NPPV duration was 6.7±2.2 days and 7.2±3.1 days in the BiPAP-S and AVAPS-S modes, respectively (p=0.39). Mean device settings and post-NPPV measurements for all sessions in both modes are shown in Table 3. There was no significant difference found between EPAP settings of BiPAP-S and AVAPS-S modes (p=0.96). When the mean ventilation variables of all sessions were calculated, there was no statistically significant difference in mean respiratory rate, minute ventilation, and amount of air leaks between the two modes. The mean PIP value in the AVAPS-S mode was statistically higher than in the BiPAP-S mode (p<0.001).

$PaCO_2$ was reduced by 10% in approximately 70% of patients within the first 5 days, and by 20% in approximately 50% of patients within the first 7 days compared to the levels at admission in both modes. No difference was found in the number of patients meeting the specified criteria for reductions in $PaCO_2$, days of response, and NPPV duration between the two modes (Table 4). Similarly, a comparison between obese (BMI≥30) and non-obese patients and those with and without an obstructive lung disease (FEV_1/FVC<0.7 and FEV_1<80%) showed no significant difference in all criteria for reduction in the carbon dioxide levels. The BiPAP-S mode resulted in a mean reduction of 2.7±2.3 mmHg in pre- and post-therapy $PaCO_2$ levels for all sessions versus a mean reduction of 5.7±4.1 mmHg

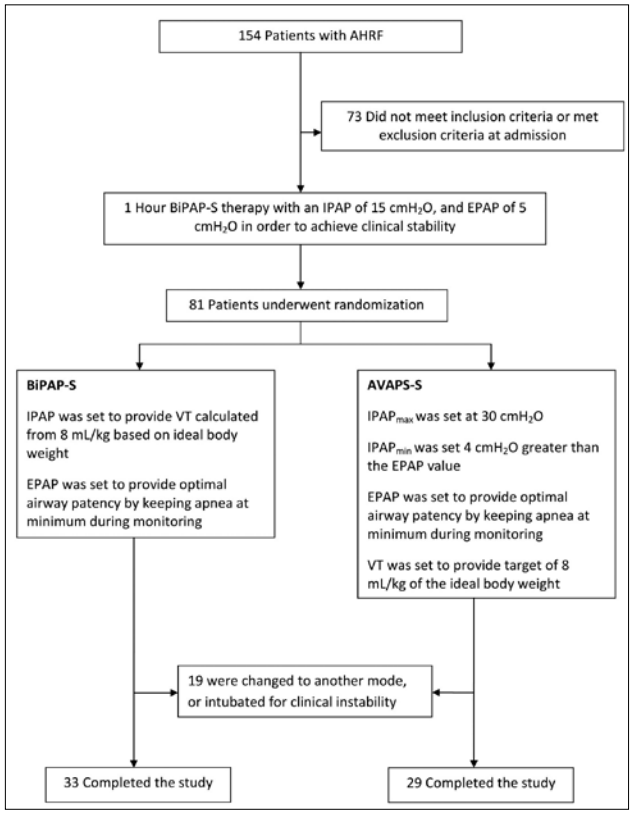

Figure 1. Schematic diagram showing flow of patients through the study

Table 1. General characteristics of all patients randomized to BiPAP-S and AVAPS-S modes

	BiPAP-S (n: 33)	AVAPS-S (n: 29)	p
Mean age±SD	63.1±12.6	65.3±11.1	0.47
Women; n (%)	15 (45.5)	13 (44.8)	0.96
BMI; kg/m^2	33.8±10.5	33.4±10.8	0.9
BMI≥30 kg/m^2; n (%)	17 (51.5)	16 (55.2)	0.8
Ever smoker; package-years ± SD	44.6±41.1	37.3±20.3	0.49
APACHE-II score	17.1±5.6	17.8±5.3	0.6
Comorbidities; n (%)			
Cardiac diseases	27 (81.8)	24 (82.8)	0.92
Diabetes mellitus	10 (30.3)	7 (24.1)	0.59
Other	3 (9.1)	2 (6.9)	0.99
Long-term oxygen therapy; n (%)	24 (72.7)	16 (55.2)	0.15
NIV at home; n (%)	10 (30.3)	7 (24.1)	0.59

BMI: body mass index; SD: standard deviation; APACHE: acute physiology and chronic health evaluation; NIV: non-invasive ventilation.

Table 2. Results of blood gas analysis at admission, pulmonary function test, and echocardiogram at discharge

	BiPAP-S	AVAPS-S	p
pH	7.34±0.04	7.32±0.04	0.08
PaO_2; mmHg	68.9±14.6	75.3±15.3	0.09
$PaCO_2$; mmHg	62.5±5.8	65.1±7.2	0.12
SO_2; % *	92.6±3.7	92.9±4.1	0.71
HCO_3; mmol/L	33.7±4.5	33.6±6.1	0.93
FEV_1; % predicted	41.3±15.9	41.5±19.6	0.96
FVC; % predicted	53.4±16.6	48.2±17.7	0.26
FEV_1/FVC; %	62.2±15.1	66.2±19.1	0.4
EF; %	58.2±8.9	62.9±4.8	0.15
sPAP; mmHg	43.3±23.4	42.3±22.3	0.89

FEV_1: forced expiratory volume in 1 second; FVC: forced vital capacity; EF: ejection fraction; sPAP: systolic pulmonary artery pressure

* With supplemental oxygen therapy, adjusted to achieve SO2 90%-95%.

Pulmonary function tests and echocardiography were done before hospital discharge. Results are shown as mean±standard deviation.

Table 3. Device settings and post-NPPV measurements (ventilation variables)

	BiPAP-S (n=33)	AVAPS-S (n=29)	p
Device settings			
$IPAP_{max}$; cmH_2O	17.4±3.8*	30	-
$IPAP_{min}$; cmH_2O	-	11±2.2	-
EPAP; cmH_2O	6.9±2.1	7±2.1	0.96
VT; ml	-	500±43.5	-
Post-NPPV measurements; mean of all sessions			
PIP; cmH_2O	17.5±3.5	22.2±5.1	0.001
MV; L/min	10.2±1.9	10.3±2.5	0.81
Leak; L/min	27.8±5.4	26.5±3.8	0.29
Respiratory rate	22.2±3.5	22.7±4.1	0.61

IPAP: inspiratory positive airway pressure; EPAP: expiratory positive airway pressure; VT: tidal volume; PIP: peak inspiratory pressure; MV: mean ventilation

*IPAP in BiPAP-S mode is shown in this cell. Results are shown as mean±standard deviation.

with the AVAPS-S mode. Repeated measures ANOVA that was performed to compare the changes in $PaCO_2$ levels by selected mode within the first 6 days showed no statistically significant difference (F=0.355, p=0.56). Similar results were obtained with the changes in HCO_3 and pH levels (F=2.588, p=0.12 and F=0.321, p=0.57, respectively) (Figure 2). When MV, air leaks, RR, and PIP values were compared by days, there was no statistically significant difference in the values, except for the PIP at days 1 and 2, and air leaks at day 3 (Table 5). Post hoc analysis showed that the difference in PIP between the two modes was remarkable only during the first 2 days. Furthermore, a comparison of the daily $PaCO_2$ curves for each mode

Table 4. Comparison of the amount and time of decrease in $PaCO_2$ levels, NPPV duration, and length of ICU stay of the patients according to treatment groups

	BiPAP-S	AVAPS-S	p
Comparison of post-NPPV $PaCO_2$ values as a percentage of admission			
10% decrease; n (%)	24 (72.7)	20 (71.4)	0.91
The time of 10% decrease; days±SD	5.1±1.9	4.6±2.6	0.53
Mean NPPV application time for 10% decrease; hours±SD	39.7±21.7	35.6±23.7	0.55
20% decrease; n (%)	15 (45.5)	15 (53.6)	0.53
The day of 20% decrease; days±SD	6.1±2.2	6.2±3.1	0.95
Mean NPPV application time for 20% decrease; hours±SD	50.6±25.2	48.2±27.2	0.8

NPPV: Non-invasive positive pressure ventilation; SD: standard deviation

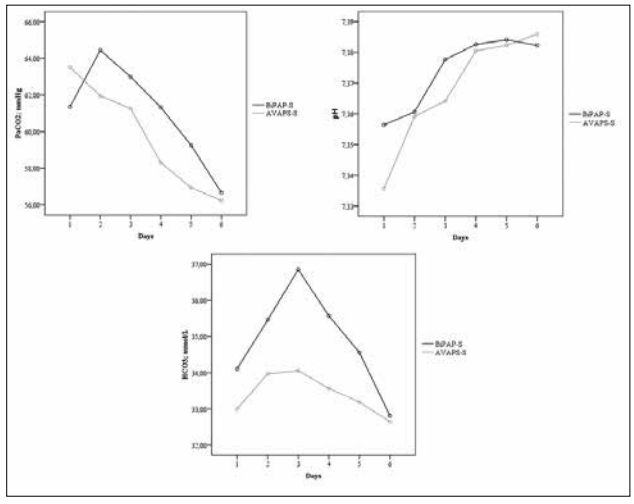

Figure 2. Changes in the mean daily $PaCO_2$, pH, and HCO_3 values in the course of 6 days. Repeated measures analysis of variance showed no statistically significant difference (F=0.355, p=0.56 for PaCO2; F=0.321, p=0.57 for pH; F=2.588, p=0.12 for HCO3, respectively)

showed an increase in the $PaCO_2$ level within the first 48 hours in the BiPAP-S mode versus a decrease in the $PaCO_2$ level from the first session in the AVAPS-S mode. The change in $PaCO_2$ for 6 days was compared between obese (BMI≥30) and non-obese patients within BiPAP-S and AVAPS-S modes separately, and no significant difference was found (Figure 3).

Both semi-recumbent and lateral positions were used during NPPV throughout the monitoring period in both modes. The mean ventilation variables obtained with semi-recumbent and lateral positions are shown in Table 6. A comparison of semi-recumbent and lateral sessions within both modes showed that different body positioning during NPPV caused no significant change in PIP, air leaks, and RR and MV values. No significant difference was found in reduction of $PaCO_2$ levels between semi-recumbent and lateral positions within

Table 5. Comparing daily values of mean MV, leak, PIP, and RR between BiPAP-S and AVAPS-S modes

Day	1	2	3	4	5	6
MV (L/min)						
BiPAP-S	9.5±2.4	9.1±1.7	9.3±2	10.1±2.1	10.5±1.8	9.8±1.5
AVAPS-S	8.7±2.5	9.4±2.5	9.4±2.3	9.9±2.9	9.7±2.3	10±3.2
p *	0.4	0.68	0.96	0.83	0.64	0.84
Leak (L/min)						
BiPAP-S	26.5±5.7	30.3±5.8	31.3±6.3	31.6±7.4	32.4±8.3	34±9.4
AVAPS-S	26.2±5	26.7±5.7	26.1±3.3	27.8±3.6	28±5.5	29.1±4.5
p *	0.85	0.07	0.01	0.08	0.11	0.11
PIP (cmH_2O)						
BiPAP-S	16.3±3.1	16.7±3.2	17.4±3.3	17.9±3.8	19±3.7	19.8±3.7
AVAPS-S	19.7±5.2	20.3±5.3	20.4±5.5	20.1±5.1	17.5±4.9	14.6±5.2
p *	0.02	0.02	0.06	0.18	0.36	0.21
RR						
BiPAP-S	21.9±5.5	20.1±3.6	19.5±2.3	20.3±3.5	20.3±3.1	19.7±1.9
AVAPS-S	20.9±5.5	20.5±3.9	21.6±4	22.2±4.8	21.8±4.5	21.7±3.6
p *	0.6	0.8	0.06	0.2	0.3	0.09

MV: mean ventilation; PIP: peak inspiratory pressure; RR: respiratory rate

Results are shown as mean ± standard deviation.

Table 6. Comparing post-NPPV measurements of all semi-recumbent and lateral sessions within both modes separately

	BiPAP-S			AVAPS-S		
	Semi-recumbent	**Lateral**	**p**	**Semi-recumbent**	**Lateral**	**p**
PIP; cmH_2O	17.4±3.5	17.8±3.9	0.87	22.1±4.9	21.1±5.1	0.42
MV; L/min	10.3±1.8	10.2±3.3	0.18	10.2±2.9	10.5±2.6	0.9
Leak; L/min	26.9±5.1	29.1±5.8	0.11	24.8±3.8	26.1±7.4	0.96
RR	23.4±4.6	22.1±3.1	0.07	22.6±4.9	21.8±4.2	0.57

PIP: peak inspiratory pressure; MV: mean ventilation; RR: respiratory rate

Results are shown as mean±standard deviation.

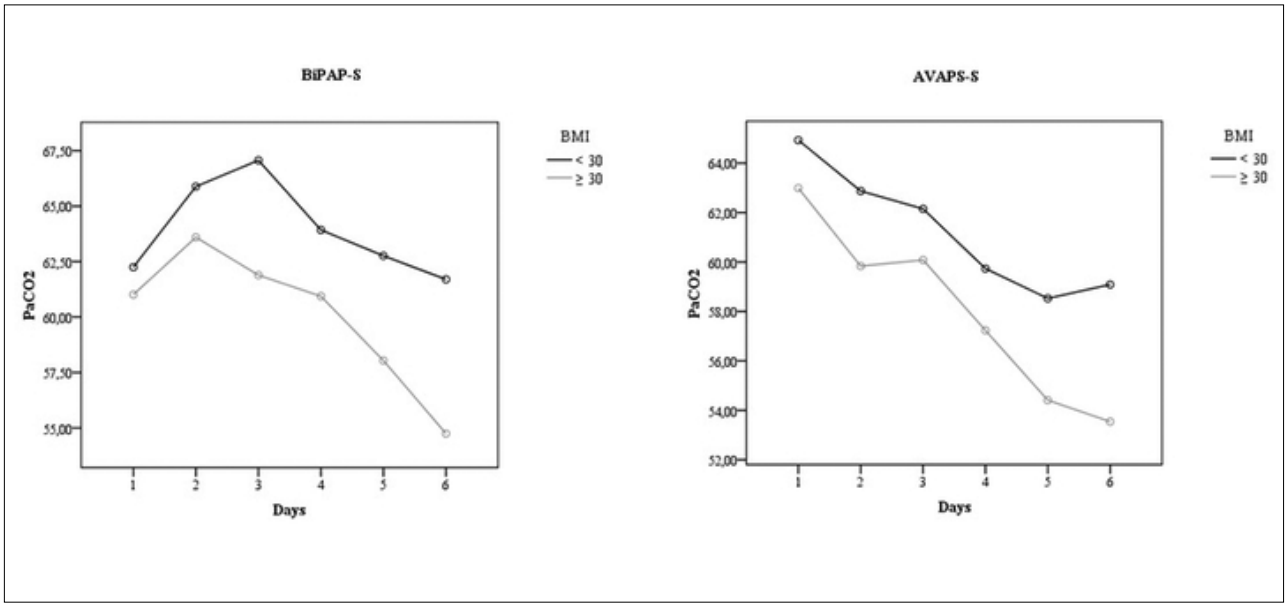

Figure 3. Changes in the mean daily $PaCO_2$ values of obese (BMI≥30) and non-obese patients. Course of $PaCO_2$ values found similar in both modes (F=3.245, p=0.053 for BiPAP-S; F=2.931, p=0.097 for AVAPS-S)

two modes ($p>0.05$). But there was a significant reduction in mean $PaCO_2$ value for all semi-recumbent and lateral NPPV sessions.

DISCUSSION

In the present study, patients with acute or acute-on-chronic hypercapnic respiratory failure were randomly assigned to either BiPAP-S or AVAPS-S modes. As primary endpoint, the changes in $PaCO_2$, HCO_3, and pH levels and length of hospital stay by both modes were found similar, with no difference between the mean MV, RR, and air leak measurements. The mean PIP was higher in the AVAPS-S mode. As secondary endpoint, the mean reduction in $PaCO_2$ per session with semi-recumbent and lateral positions in the AVAPS-S mode was remarkably higher than in the BiPAP-S mode. This difference was not observed when comparing semi-recumbent and lateral positions within both modes. The patient's position during NPPV did not make any change in the measurements of PIP, RR, air leak, and MV. Furthermore, presence of obesity had no effect on the carbon dioxide response within both modes.

Recently, NPPV has been considered to be the most important development in the field of pulmonology since it eliminates complications associated with invasive mechanical ventilation [3,13]. Studies on NPPV modes and their use usually focused on a selected group of diseases. To our best knowledge, the present study represents the first study that compared the effect of BiPAP-S and AVAPS-S modes, obesity, and body position on success in ICU settings.

Previous studies comparing both modes were generally included chronic hypercapnic patients. In a study which compared home use of BiPAP-S/T and BiPAP-AVAPS-S/T modes in 10 patients diagnosed with obesity hypoventilation syndrome (OHS), Storre et al. [14] found that the BiPAP-S/T mode improved oxygenation, sleep quality, and health-related quality of life. However, higher levels of $PaCO_2$ were not improved by therapy. Addition of the S/T-AVAPS mode to the therapy contributed to the ventilation, thus resulting in a more efficient reduction in carbon dioxide levels. Another study which enrolled 50 super obese (BMI>40 kg/m^2) patients with OHS and compared home use of BiPAP-S and BiPAP-AVAPS-S modes showed no statistically significant difference in changes of $PaCO_2$, PaO_2, and HCO_3 at the end of 3 months. There was no difference in PIP and air leaks monitored throughout the study between the two modes [15]. In our study, there were no difference in the course of $PaCO_2$, PaO_2, and HCO_3 levels between the two modes. However, the mean PIP value was higher in the AVAPS-S mode. Although no difference was observed in the repeated measures analysis of variances between the two modes, post hoc analysis showed that the difference in PIP between the two modes was remarkable only during the first two days. Furthermore, a comparison of the daily $PaCO_2$ curves for each mode showed an increase in the $PaCO_2$ level within the first 48 hours in the BiPAP-S mode versus a decrease in the $PaCO_2$ level from the first session in the AVAPS-S mode. As the mean MV, air leak, and RR measured during the therapy with both modes and the EPAP levels adjusted before the therapy were similar, the increased PIP during the first 2 days in the AVAPS-S mode indicates that the device utilized higher inspiratory pressures in order to achieve the targeted tidal volume. Therefore, it appears that the reduction in $PaCO_2$ was more effective in the AVAPS-S mode in an earlier period compared to the BiPAP-S mode. These results suggest that inspiratory pressures should be kept higher during the earlier days in patients presenting with AHRF, especially in modes with constant pressure settings.

The mean BMI in our patient group was 33.6 kg/m^2, and 53.2% of patients had a BMI of 30 kg/m^2 and over, which represents the threshold for obesity. Repeated measures ANOVA within both modes showed that presence of obesity caused no difference in the reduction of $PaCO_2$. A previous study carried out in our ICU to examine the effect of obesity on NPPV strategies and responses in patients with AHRF found that presence of obesity was not associated with the length of hospital stay, intubation rate, and mortality [16]. However, we found that obese patients should remain on NPPV 3 times longer than non-obese patients in order to reduce the $PaCO_2$ level to less than 55 mmHg, which was the primary endpoint. Another challenge in obese patients other than hypoventilation are respiratory events that occur during sleep. With apnea being the most severe event, MV is reduced, and hypercapnia deepens during sleep due to respiratory events in this group of patients. Even though our patients received NPPV support during sleep, a study by Contal et al. [17] in 10 patients with OHS showed that NPPV used in the spontaneous mode without any back-up respiratory rate was insufficient in preventing these respiratory events. However, it also showed that presence of back-up respiratory rate did not make any change in the transcutaneous $PtCO_2$ levels measured during sleep. While they included chronic hypercapnic patients, our study showed no negative effect of obesity on the $PaCO_2$ response in a group of acute hypercapnic patients. Since both modes used in our study were spontaneous modes without any back-up respiratory support, such back-up may not be required in acute patients.

In the present study, the BiPAP-S mode resulted in a significantly less mean reduction in pre- and post-therapy $PaCO_2$ levels for all sessions compared to AVAPS-S mode. Although the mean reduction in $PaCO_2$ levels obtained in the AVAPS-S mode per session is almost 100% higher than in the BiPAP-S mode, it is questionable whether there is a similar course of reduction, rate of meeting the reduction criteria in $PaCO_2$, and length of ICU stay. It indicates that in patients with acute hypercapnic respiratory failure, the reduction in $PaCO_2$ with a single session of NPPV will not be permanent due to ongoing underlying pathology associated with acute deterioration. However, application of AVAPS-S mode in early period of disease would reduce carbon dioxide level more effectively, and that might decrease the rate of endotracheal intubation in these patients.

When the relationship between different body positions, $PaCO_2$ response, and respiratory mechanics is considered, Thomas et al. [18] found that lateral positioning had no effect on PaO_2/FiO_2 in ventilated intensive care patients. An-

other study observed that body positioning had no effect on respiratory patterns and dynamics during NPPV therapy in patients with stable COPD. There was no difference in RR, VT, and MV levels in the BiPAP-S mode between semi-recumbent and lateral positions in the groups [19].

In a study evaluating the effect of BiPAP-S and AVAPS-S modes in semi-recumbent and lateral positions during sleep on sleep efficiency and MV, Ambrogio et al. [20] showed that semi-recumbent position was associated with worse sleep efficiency. With the use of AVAPS-S mode in lateral positioning, MV remained stable as the stage of sleep increased. There was a remarkable reduction in MV with increased stages of sleep with the BiPAP-S mode in both positions and AVAPS-S in semi-recumbent position. Furthermore, similar to our study, there was no difference in minute ventilations between semi-recumbent and lateral sessions. Thus, we may interpret the absence of any difference between different positions in the same mode, as causes of hypoventilation such as upper-airway obstruction in semi-recumbent position and increased abdominal pressure associated with abdominal fat tissue can be partially prevented with appropriate pressure support and monitorization. Unlike our study, this study was carried out with a group of chronic respiratory failure patients with stable COPD. The effect of selected mode and positions on the quality of sleep was evaluated by polysomnographic recording. Since our study included intensive care patients in the acute phase, our priority was to evaluate the effect of selected mode and position on the reduction in carbon dioxide levels.

Even if it was not one of our objectives, we concluded that variations in pressure requirements during patient monitoring can be met by evaluating the recordings taken during NPPV therapy. The pressure requirements particularly during sleep and wakefulness are completely different. Fanfulla et al. [21], in a study in 48 patients with chronic respiratory failure, showed patient-ventilator asynchrony during sleep with ventilators adjusted for daytime conditions and recommended that presence of asynchrony should be identified by monitoring patients who were scheduled for long-term NPPV therapy.

Our study has some limitations. First of all, each patient had more than one outcome for semi-recumbent and lateral positions. Even though we obtained a mean value, we didn't examine the long-term effect of body positioning in the selected mode. We can attribute this to the unwillingness of patients to remain in semi-recumbent or lateral position for a long period of time. Long-term effects associated with positioning can be shown with studies monitoring patients in the same position for longer periods. Second, we evaluated the efficacy of non-invasive mechanical ventilation based on the monitoring facilities of the device (respiratory rate, air leaks, minute ventilation), but we didn't make any polysomnographic examination to evaluate respiratory pattern, apnea/hypopnea features, and sleep quality. However, as mentioned before, polysomnographic examination fails to provide an accurate and reliable evaluation in the group of acute intensive care patients; it is mostly beneficial particularly in determining the most appropriate mode and the most accurate pressures during the planning phase of long-term non-invasive mechanical ventilation before the discharge. Third, our study was carried out in a single center with a small group of patients, and finally, post hoc power analysis indicated that the power wasn't sufficient (0.27) given the group sizes and length of ICU stay.

In conclusion, although the decrease in the carbon dioxide levels with the AVAPS-S mode per session was remarkably high, the course was similar with both modes. Furthermore, obesity and body positioning had no prominent effect on the carbon dioxide response and ventilator mechanics.

Ethics Committee Approval: Ethics committee approval was received for this study from Gazi University Clinical Research Ethics Committee (Approval Date: 15.06.2011/Approval No: 226).

Informed Consent: Written informed consent was obtained from the patient who participated in this study.

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